

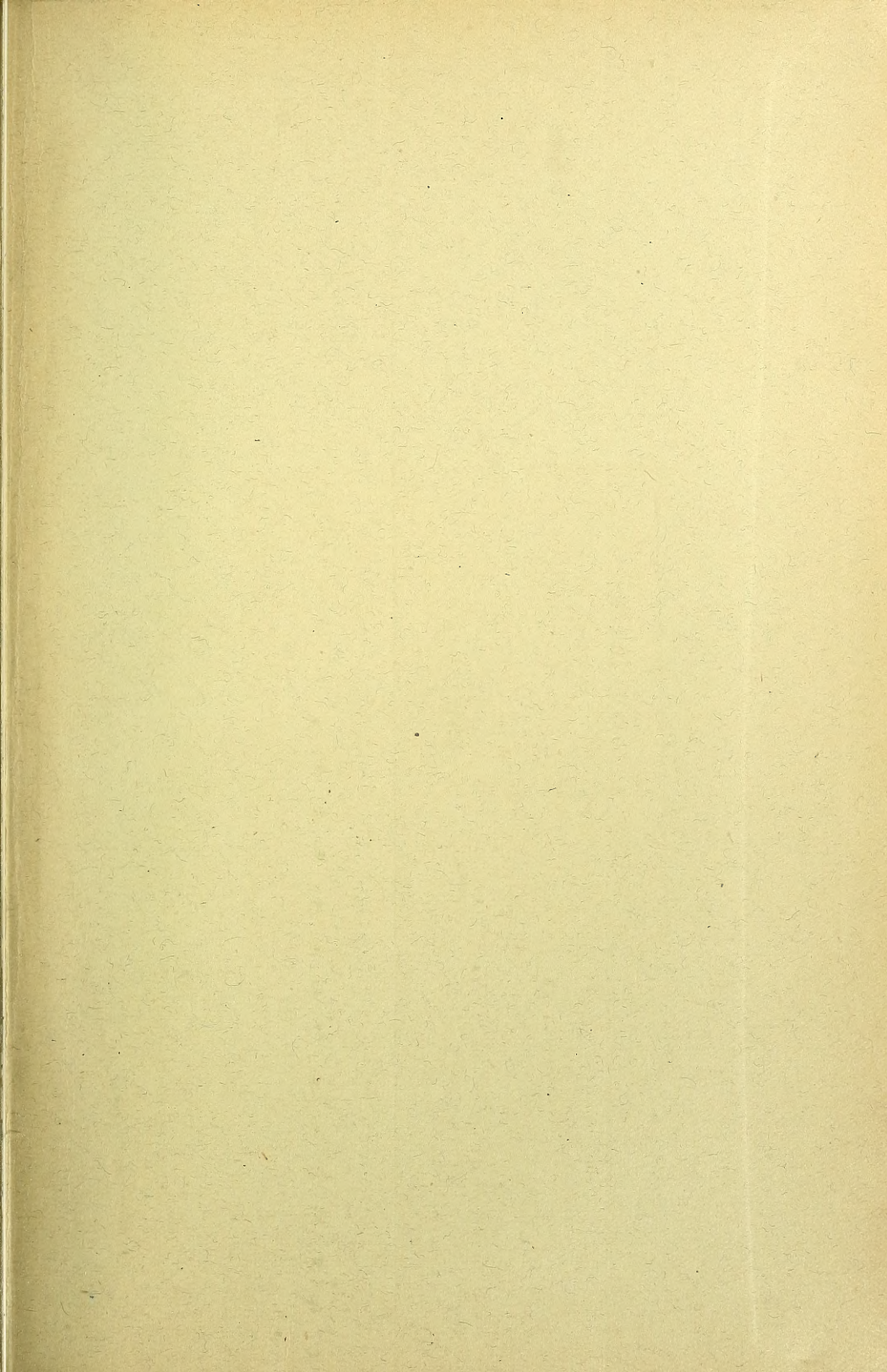
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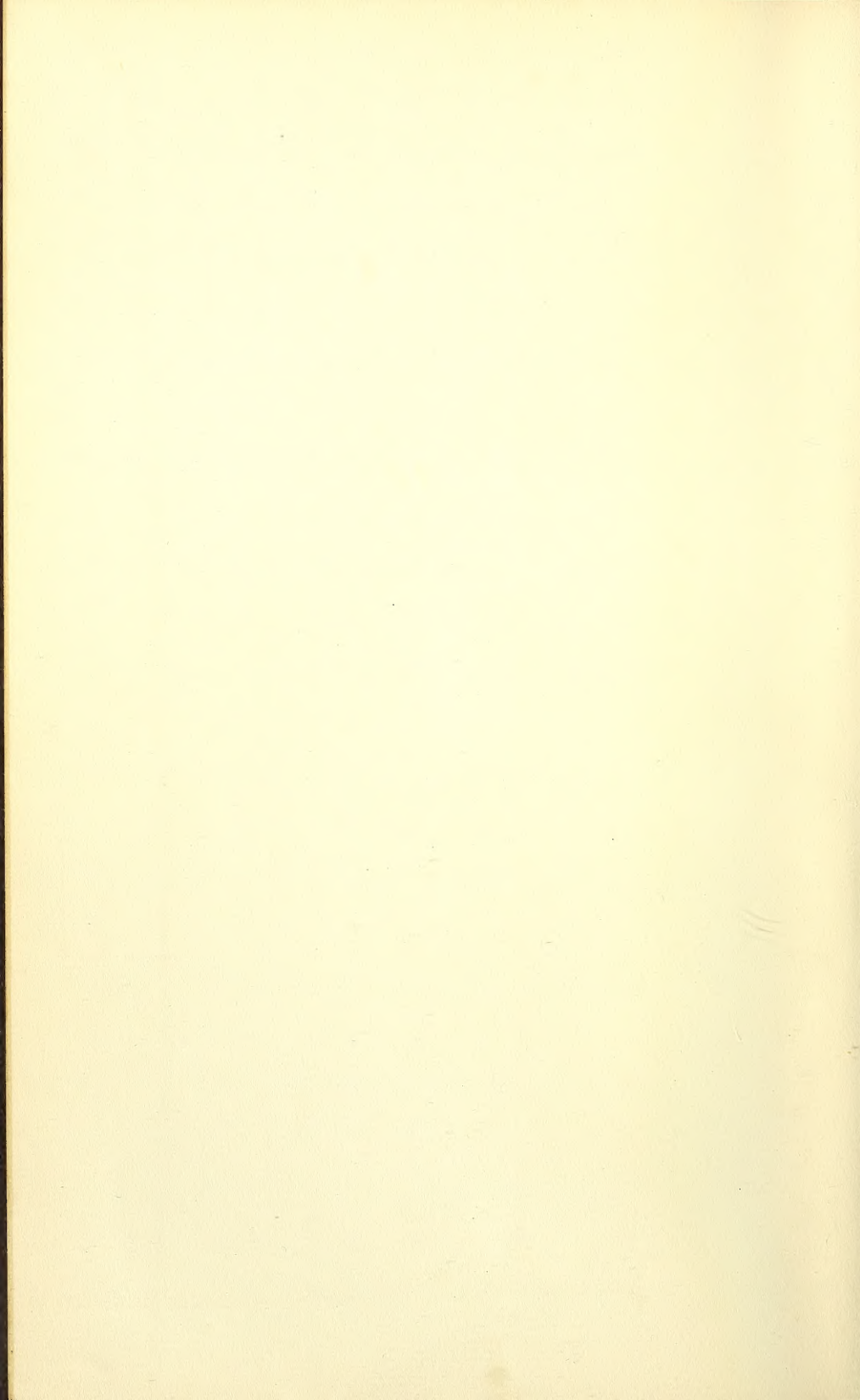
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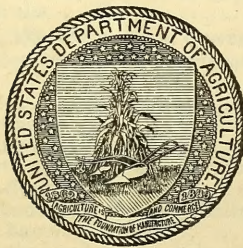
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**THE TERRAPIN SCALE:¹ AN IMPORTANT INSECT
ENEMY OF PEACH ORCHARDS.**By F. L. SIMANTON, *Entomological Assistant, Deciduous Fruit Insect Investigations.***CONTENTS.**

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INTRODUCTION.

For several years the terrapin scale, *Eulecanium mnigrofasciatum* Pergande, has been increasing in abundance in certain localities in the eastern United States, and complaints have recently come to the Bureau of Entomology from orchardists in numerous localities within the Appalachian peach belt of severe injury to peaches, and of inability to control the insect with the materials commonly used.

In order to investigate the insect under favorable conditions the Office of Deciduous Fruit Insect Investigations of the Bureau of Entomology maintained a field laboratory during the seasons of 1912 and 1913 at Mont Alto, Pa., which is well within the limits of the badly infested area. The following pages contain a record of the life-history studies made, together with a short historical account of the species. A detailed account is also given of its habits and of the remedies that have been devised for its control.

The author wishes to acknowledge the assistance of Dr. A. L. Quaintance, under whose direction this investigation was conducted, and to thank Messrs. D. M. Wertz and Aaron Newcomer for the use of their orchards and spraying machinery.

¹ *Eulecanium nigrofasciatum* Pergande.

HISTORY.

The terrapin scale, *Eulecanium nigrofasciatum* Pergande, is a native species which came to the notice of economic entomologists about 1870. Mr. Theodore Pergande, of the Bureau of Entomology, observed it as early as 1872. It was then believed to be the European scale *Lecanium persicae* Fab., an insect of similar habits. The publications prior to 1898, for the most part, refer to it under the latter name. Miss Mary E. Murtfeldt was the first writer to treat of this insect at any length. She observed it in 1893, at Kirkwood, Mo., but did not completely work out its life history. Her observations are recorded in Bulletin 32 [old series] of the Division of Entomology, United States Department of Agriculture (1893), under the name *Lecanium persicae* Fab.

Dr. L. O. Howard treated this species in the Yearbook of the United States Department of Agriculture for 1894 under the name *Lecanium persicae* Modeer, and there figured it for the first time.

Mr. Theodore Pergande became convinced that this lecanium was distinct from *L. persicae* Fab., and described it in Bulletin 18 [new series], Division of Entomology, United States Department of Agriculture (1898), as *Lecanium nigrofasciatum*, new species.

Since about 1898 the terrapin scale has gradually assumed more and more importance as an enemy of the peach, until now it is feared by the peach growers of Maryland and Pennsylvania more than any other species of scale insect. Most of the States east of the one hundredth meridian have mentioned this pest in their entomological publications during the last 10 years. At the present time it appears to be most abundant in portions of Maryland and Pennsylvania.

DISTRIBUTION.

There are no indications that the terrapin scale occurs outside of North America. It is at present, for the most part, confined to the humid area of the Austral Region, but there is danger that it may ultimately invade western peach orchards, especially those in the Austral Zones. This species has been taken in New Mexico and is doubtfully reported from southwestern Colorado, but, so far as known, it does not now occur in the other Western States. It has a slight foothold in Ontario Province, Canada, mostly upon maple. At the present time considerably more than one-half of all the known infestations are found in Pennsylvania and Maryland. (See fig. 1.)

In general this scale has advanced into the region of its principal food plants, having spread through the peach belt of the Eastern United States, and progressed northward beyond this belt by attacking ornamental trees, of which the maples and sycamores seem to be its favorite hosts. It has also extended its range in the Southwest

by attacking the mistletoe, upon which it thrives very well. It will undoubtedly spread considerably beyond its present range by advancing farther into the territory of its chief host plants. Those regions in which the peach, the plum, the maple, the sycamore, and the mistletoe are abundant probably offer suitable conditions for its growth.

ECONOMIC IMPORTANCE.

The terrapin scale, in its range and importance, ranks easily as second among the scale pests of the peach, and while not so prolific and not so injurious as the San Jose scale, *Aspidiotus perniciosus*



FIG. 1.—Distribution in the United States of the terrapin scale (*Eulecanium nigrofasciatum*). (Original.)

Comstock, it is even more of a nuisance, owing to the difficulty met with in its control.

INJURY.

This insect causes injury first, by sucking the sap from the trees, and second, by covering the fruit, leaves, and branches with a sweet sticky fluid known as honeydew.

The injury to the trees from the loss of sap taken by the scale is considerable in badly infested orchards, but is small in comparison with the damage resulting from the deposit of honeydew. This deposit, while objectionable, would not cause serious injury were it not for a black or sooty fungus which grows abundantly in the honeydew whenever this is present. On trees which are badly infested with the scale the fruit soon becomes covered with a black sticky coat which makes it almost unsalable, as it is nearly all classed as culls and is sold accordingly.

FOOD PLANTS.

Eulecanium nigrofasciatum attacks more than 30 species of plants. It becomes abundant, however, upon only a comparatively few of these. Its preference for its principal food plants is about in the following order: Peach, plum, maple, cherry, sycamore, mistletoe.

The following list includes all of the host plants known to the author:

<i>Acer pseudoplatanus</i> L. Sycamore maple.	<i>Nerium oleander</i> L. Oleander. Rose bay.
<i>Acer saccharinum</i> L. Silver maple. -	<i>Ollea</i> sp. Olive.
<i>Acer saccharum</i> Marsh. Sugar or rock maple.	<i>Padus</i> sp. Wild cherry.
<i>Amygdalus persica</i> L. and var. Peach and nectarine.	<i>Phoradendron</i> sp. Mistletoe.
<i>Benzoin aestivale</i> (L.) Nees. Spice-bush.	<i>Platanus occidentalis</i> L. Sycamore or plane-tree.
<i>Betula</i> sp. Birch.	<i>Platanus orientalis</i> L. European plane-tree.
<i>Bumelia angustifolia</i> Nutt. Saffron plum.	<i>Populus deltoides</i> Marsh. Cottonwood.
<i>Castanea dentata</i> (Marsh.) Borkh. Chestnut.	<i>Prunus sinconii</i> Carr. Simon or apricot plum.
<i>Cercis canadensis</i> L. Red-bud.	<i>Prunus</i> spp. Cultivated and wild cherries and plums.
<i>Chaenomeles japonica</i> Lindl. Japan quince.	<i>Pyrus communis</i> L. Pear.
<i>Clematis</i> sp. Clematis.	<i>Pyrus malus</i> (L.) Britton. Apple.
<i>Crataegus oxyacantha</i> L. Hawthorn.	<i>Quercus virginiana</i> Mill. Live oak.
<i>Crataegus</i> . Most species.	<i>Ribes</i> sp. Gooseberry.
<i>Cydonia oblonga</i> Mill. Quince.	<i>Rosa</i> spp. Roses.
<i>Elaeagnus angustifolia</i> L. Oleaster.	<i>Salix babylonica</i> L. Weeping willow.
<i>Euonymus atropurpureus</i> Jacq. Wahoo or burning bush.	<i>Salix</i> spp. Willows.
<i>Fraxinus</i> sp. Ash.	<i>Sapindus marginatus</i> Willd. Soapberry.
<i>Ilex opaca</i> Ait. American or white holly.	<i>Tilia</i> sp. Linden or basswood.
<i>Magnolia virginiana</i> L. Sweet bay.	Umbelliferae. One species.
<i>Melia azedarach</i> L. Wild China-tree.	<i>Vaccinium</i> spp. Blueberries.
<i>Morus</i> spp. Mulberry.	<i>Vitis vinifera</i> L. European grape.
	<i>Vitis</i> spp.

LIFE HISTORY.

MATURING OF FEMALES IN SPRING.

Hibernation is terminated by weather conditions. The conditions that cause the peach buds to open also bring this lecanium to the end of hibernation. At Mont Alto, Pa., in 1913, hibernation ended about April 1, at which time many blossoms were ready to burst. From April 1 to May 1 growth was rapid. From May 1 to May 16 it was comparatively slow. At the latter date the advanced females reached their maximum size, which they retained until the period of reproduction was nearly over. All the females had reached maturity by June 10. Table I shows the minimum, maximum, and average sizes of 414 specimens measured during the spring development and the reproduction periods of 1912 and 1913 at Mont Alto, Pa.

This material was taken from vigorous trees. Twigs containing about 200 specimens were cut to secure material for each measurement. To overcome the natural variation in size the 50 largest specimens were removed from the twigs and the largest of these taken each time for measuring. These measurements show the following maxima:

Length, May 16, 1912.....	3.7 mm.
Width, May 30, 1912.....	3.35 mm.
Height, May 24, 1913.....	1.60 mm.

TABLE I.—Measurements showing growth of 414 females of the terrapin scale during the spring development, Mont Alto, Pa., 1912 and 1913.

Date.	Number of specimens.	Length.			Width.			Height.		
		Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.	Minimum.	Maximum.	Average.
		<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>
Feb. 24, 1913.....	25	1.80	2.375	2.076	1.8	2.275	2.030	0.725	1.10	0.908
Mar. 28, 1913.....	20	1.726	2.053	1.891	1.633	2.146	1.758	.65	.85	.741
Apr. 8, 1913.....	20	1.825	2.31	2.114	1.87	2.255	2.060	.73	.975	.854
Apr. 10, 1912.....	10	1.81	2.2	1.995	1.75	2.2	1.905	.8	1.15	.949
Apr. 11, 1912.....	3	1.85	1.9	1.88	1.8	1.9	1.833			
Apr. 16, 1912.....	13	1.6	2.55	1.926	1.5	2.35	1.828			
Apr. 17, 1913.....	20	1.87	2.53	2.195	1.842	2.365	2.037	.865	1.1	.953
Apr. 19, 1912.....	10	2.05	2.7	2.372	2.1	2.375	2.302	.825	1.00	.922
Apr. 22, 1912.....	10	1.7	2.3	2.057	1.6	2.25	1.900			
Apr. 23, 1913.....	20	2.24	2.98	2.576	1.82	2.613	2.298	.85	1.225	.995
Apr. 26, 1912.....	10	1.975	2.925	2.314	1.725	2.625	2.200			
Apr. 28, 1913.....	20	2.613	3.427	2.866	2.24	3.033	2.566	.925	1.275	1.118
Apr. 30, 1913.....	20	2.706	3.042	2.94	2.473	2.94	2.721	1.00	1.3	1.165
May 6, 1912.....	6	2.5	2.975	2.666	2.3	2.675	2.458	1.00	1.25	1.437
May 7, 1913.....	20	2.893	3.22	3.024	2.501	2.893	2.639	1.2	1.50	1.343
May 10, 1913.....	20	2.8	3.266	3.021	2.52	2.893	2.674	1.05	1.50	1.317
May 16, 1912.....	10	2.65	3.7	3.127	2.65	3.3	2.94			
May 16, 1913.....	20	2.94	3.621	3.204	2.52	3.173	2.951	1.225	1.19	1.365
May 23, 1913.....	20	2.8	3.38	3.046	2.61	3.22	2.851	1.15	1.475	1.333
May 24, 1913.....	20	2.8	3.36	3.170	2.706	3.266	2.950	1.225	1.60	1.435
May 30, 1912.....	7	2.5	3.525	3.217	2.7	3.35	3.067	1.07	1.43	1.352
May 31, 1913.....	20	2.983	3.453	3.177	2.613	2.986	2.844	1.20	1.49	1.319
June 3, 1913.....	20	2.893	3.593	3.113	2.613	3.08	2.811	1.20	1.55	1.392
June 5, 1912.....	2	3.05	3.5	3.275	2.5	3.1	2.8	1.325	1.375	1.35
June 7, 1913.....	20	2.8	3.36	3.102	2.66	3.22	2.885	1.275	1.525	1.383
June 20, 1913.....	20	2.52	3.173	2.947	2.426	2.986	2.717	1.22	1.525	1.384
June 28, 1912.....	8	2.6	3.05	2.887	2.7	3.30	2.85	1.075	1.5	1.282
Total.....	414									

It is doubtful whether individuals ever are large enough to have all the above measurements, since excessive size in one dimension is accompanied by a smaller size in the other dimensions.

The date of greatest average measurements of the same 414 specimens are:

	<i>Mm.</i>
May 30, 1912, length (7 specimens).....	3.217
May 30, 1912, width (7 specimens).....	3.067
May 6, 1912, height (6 specimens).....	1.437

It is evident from these data that the females reach their maximum size between the middle of May and the end of the first week in June.

THE EMBRYO.

The terrapin scale is viviparous. Authors making reference in literature to the eggs of this insect undoubtedly referred to the embryos, which probably were mistaken for eggs. Undeveloped eggs are present in some specimens in the fall before hibernation. Dissections made September 9, 1913, showed a pair of very small racemose ovaries containing a few undeveloped eggs located to the right and left of the alimentary canal, and a small, globular, brown-colored receptaculum seminis attached to the vagina. Dr. Quaintance has observed eggs in hibernating females from Winchester, Va., as early as January 19. The writer has taken rudimentary eggs at various times during the hibernating period. With the renewal of growth in the spring there is a rapid increase in both the number and size of the eggs. The average size of four embryos at birth was as follows: Length, 0.3437 mm.; width, 0.1625 mm.

The data in Table II were taken from the largest embryos obtained at each dissection. Some of these were nearly full size by May 16, although it was not until the first week in June that the eyespots and segments became prominent.

TABLE II.—*Measurements of developing embryos of the terrapin scale, taken by dissection, 1913.*

Date.	Number of specimens.	Average length.	Average diameter.	Locality.
		<i>Mm.</i>	<i>Mm.</i>	
May 10.....	5	0.2986	0.1754	Mont Alto, Pa.
16.....	4	.3343	.1781	Do.
17.....	5	.32	.184	Do.
23.....	5	.344	.173	Do.
27.....	5	.346	.1625	Midvale, Pa.
June 28 ¹	4	.3437	.1625	Mont Alto, Pa.

¹ Measured at birth.

The ovaries remain active and continue to produce eggs as long as nutriment is supplied to them. They are among the last organs of the scale to disintegrate.

Table III gives data from dissections during the spring of 1912 and 1913. These counts show that most of the embryos are formed before the end of May. The greatest number found was 881 on June 4, 1913, and the ovaries of the parent scale were still active. It is evident from this that vigorous females may produce as many as 900 embryos. The oldest embryos are far advanced by June 6, and they are mature by June 15, at which time the eyes, the appendages, and the abdominal segments were clearly seen through the membrane.

TABLE III.—*Rudimentary eggs and embryos from developing females of the terrapin scale, taken at Mont Alto, Pa., during the seasons of 1912 and 1913.*

Date of dissection.	Females dissected on given dates.	Large embryos.	Rudimentary eggs.	Date of dissection.	Females dissected on given dates.	Large embryos.	Rudimentary eggs.
1912.				1912.			
May 27.....	1	604	Many.	June 15.....	1	747	Few.
May 28.....	1	271	Do.	Do.....	2	611	Many.
Do.....	2	297	Do.				
May 29.....	1	349	Do.	1913.			
Do.....	2	386	Do.	May 16.....	1	632	Do.
May 30.....	1	625	Do.	June 4.....	1	881	Do.
Do.....	2	463	Do.	June 7.....	1	734	Do.
Do.....	3	573	Do.	Do.....	2	758	Do.
June 5.....	1	362	Do.	Do.....	3	689	Do.
Do.....	2	696	Do.	Do.....	4	785	Do.
June 6.....	1	824	Few.	Do.....	5	663	Do.
June 7.....	1	684	Do.	Do.....	6	598	Do.

The data given in Table IV show the number of embryos produced by 13 normal scales during the season of 1912. These data were obtained by isolating the individual scales with tree tangle-foot and taking the daily emergence. When these scales loosened at the end of their reproductive periods they were removed and dissected. The average number of embryos per scale was 406.34. In this experiment approximately 50 per cent of the embryos that formed appeared as migrating larvæ.

TABLE IV.—*Record of progeny and embryos from 13 parent terrapin scales, season of 1912, at Mont Alto, Pa.*

No.	Date of dissection.	Number of embryos, emerging as larvæ.	Embryos taken by dissection.	Total embryos.	Condition of embryos removed by dissection.	Condition of scale when taken for dissection.
1.....	1912. July 12	142	451	593	One-third dead.....	Loose and exhausted.
2.....	15	189	60	249	Mostly dead.....	Do.
3.....	3	214	204	418	do.....	Do.
4.....	15	245	218	463	do.....	Nearly exhausted.
5.....	15	189	192	381	do.....	Exhausted.
6.....	10	137	37	174	All dead.....	Do.
7.....	15	119	150	269	do.....	Do.
8.....	12	303	326	629	One-fourth dead.....	Black; nearly exhausted.
9.....	15	220	195	415	Mostly dead.....	Nearly exhausted.
10.....	15	168	138	306	All dead.....	Exhausted.
11.....	15	187	22	209	do.....	Do.
12.....	15	349	193	542	do.....	Do.
13.....	15	291	343	634	do.....	Do.
Total.....		2,753	2,529	5,282		

It will be noticed from Table IV that most of these scales were removed for dissection upon July 15. These scales were among the most advanced in the orchard. Their exhaustion in the middle of July does not therefore represent the end of reproduction in the orchard, which came much later.

BIRTH OF THE TERRAPIN SCALE, AS OBSERVED AT MONT ALTO, PA., IN 1913.

The following data were obtained by observing 50 scales which gave birth to 3,000 young during the period of 4 days, June 22 to June 26, 1913:

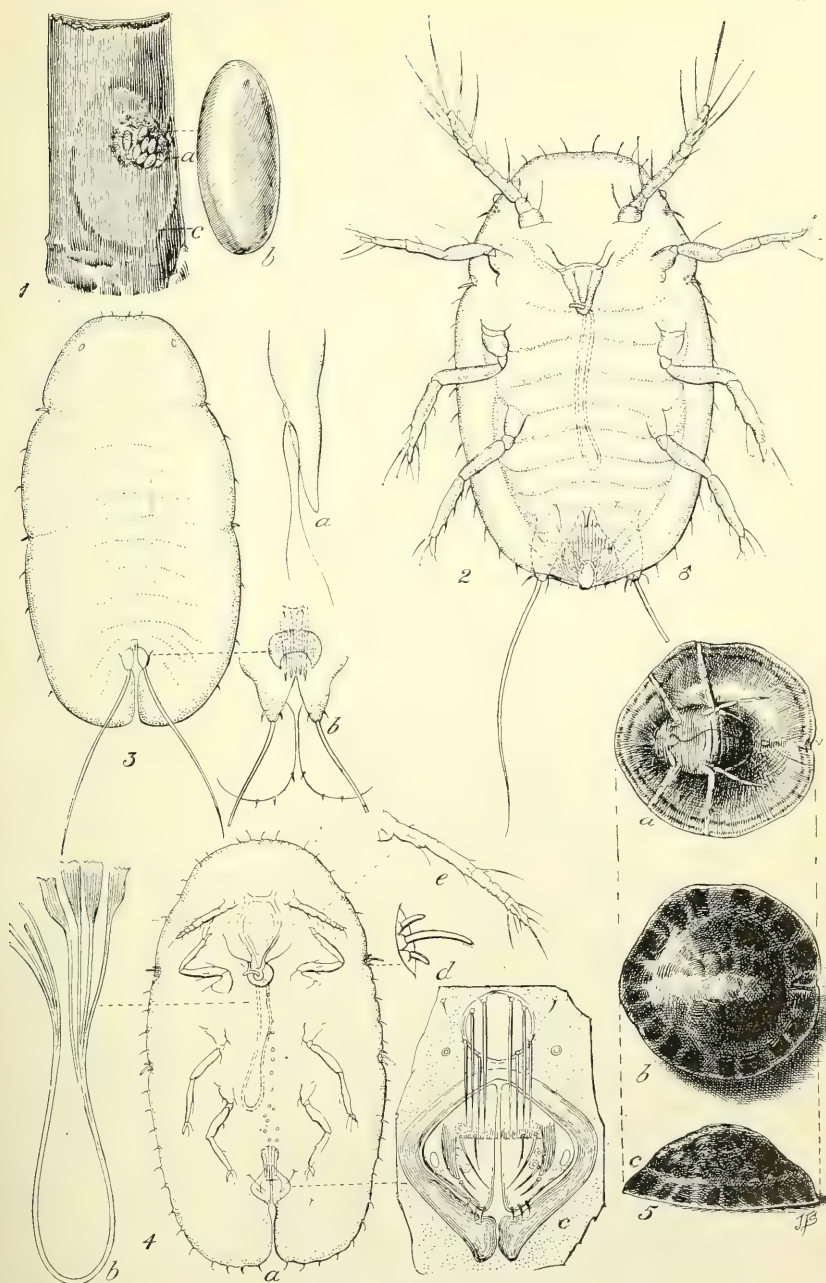
The young are brought forth as embryos, usually inside of a sac or amniotic membrane. The vaginal passage of the mother offers considerable resistance to the passage of the first young of the season, as they are very turgid or swollen, and the amniotic sac is nearly always ruptured, allowing the embryo to escape. This is the only time when they are born free, as later in the season the embryonic sac comes through unbroken. Toward the end of the season the larvæ, after birth, may remain as long as 8 minutes in the embryonic membrane, but the time is seldom more than 4 minutes. The embryos have an average length of 0.36 mm., and a transverse diameter averaging 0.18 mm. (Pl. I, fig. 1, *b*.)

The structure of the larva shows through the amniotic membrane. The antennæ are folded downward and lie parallel along the ventral surface. The proboscis lies between the antennæ and extends along the midventral line for three-fourths of the length of the body. The legs lie alongside the antennæ and extend beyond them to near the posterior end of the body. The major apical setæ and the anal plates are folded forward upon the ventral surface of the body. The eyes show prominently through the membrane. The sides of the body are rolled slightly inward, so as nearly to enfold the ventral appendages. When the embryonic membrane bursts the young appears as a wet, flat larva, which remains motionless for a few minutes, during which the body unfolds and the appendages assume their normal position. The cast membranes of the numerous progeny remain and form a deposit on the floor of the brood chamber. (Pl. I, fig. 1, *a*.) Twenty minutes after birth the larvæ have assumed their characteristic flatness and are moving about in the brood chamber, where they remain usually until the following day, or even longer if unfavorable weather conditions prevail.

Observations of birth are difficult. The displacement necessary for observing this operation loosens the feeding tube and so deprives the parent of the needed nutriment. It is, therefore, impractical to make observations covering an extended interval.

At the beginning of reproduction the time between births may be as short as 2 minutes. As the exhaustion of the parent increases the interval between births becomes longer, until by the thirtieth day birth has practically stopped.

Table V gives birth data for 7 larvæ from well-exhausted parents, under favorable conditions. It shows an average interval between births of 8.5 minutes and the average time per birth as 2.43 minutes. These birth data can be taken as a good average for the major part



THE TERRAPIN SCALE.

FIG. 1.—Embryos and larvæ as disclosed by removing a female near the end of reproduction: *a*, Embryos in situ; *b*, embryo enlarged; *c*, area covered by the scale. (Enlarged.) FIG. 2.—First-instar male at the leafward migration. (Greatly enlarged.) FIG. 3.—Leaf-attached larva near the end of the first instar: *a*, Lateral view of the caudal extremity; *b*, enlargement of the anal plates. (Greatly enlarged.) FIG. 4.—Female at twigward migration (greatly enlarged): *a*, Anal cleft (greatly enlarged); *b*, enlarged mouth parts; *c*, ventral view of the anal plates; *d*, spiracular spines, more enlarged; *e*, antenna, more enlarged. FIG. 5.—The mature female: *a*, Ventral view; *b*, dorsal view; *c*, lateral view. (Enlarged.) (Original.)

of the reproductive period. The averages are too long, however, for the first 3 or 4 days of reproduction.

TABLE V.—*Birth data of 7 larvæ of the terrapin scale under favorable conditions, Mont Alto, Pa.*

Females.	Number of larvæ.	Temperature at start.	Embryo at orifice.	Birth completed.	Time required.	Interval between births.	Date.	Degree of exhaustion of the female.	Atmospheric conditions.
		° F.	a. m.	a. m.	Minutes.	Minutes.	1913.	Per cent.	
I.....	1	75	7.14	7.17	3	-----	June 24	70	Favorable.
I.....	2	75	7.24	7.28	4	11	do.....	70	Do.
I.....	3	75	7.35	7.36	1	8	do.....	70	Do.
II.....	1	75	7.16	7.18	2	-----	do.....	70	Do.
II.....	2	75	7.24	7.27	3	9	do.....	70	Do.
II.....	3	75	7.31	7.33	2	6	do.....	70	Do.
III.....	1	75	8.07	8.09	2	-----	do.....	70	Do.
Average.	-----	75	-----	-----	2.43	8.5	-----	-----	-----

Table VI gives data for 7 larvæ from two well-exhausted parents under rather unfavorable conditions. These data show an average interval between births of 13.87 minutes. They also show that the interval varies widely in the case of different individuals.

TABLE VI.—*Birth data for the terrapin scale under unfavorable conditions, Mont Alto, Pa., 1913.*

Female.	Number of larvæ.	Temperature at start.	Time of birth.	Interval between births.	Date.	Degree of exhaustion.	Weather conditions.
		° F.	a. m.	Minutes.	1913.	Per cent.	
I.....	1	74	7.37	-----	June 13	70	Unfavorable.
	2	74	7.43	6	do.....	70	Do.
	3	75	7.50	7	do.....	70	Do.
	4	76	8.05	15	do.....	70	Do.
Average for first female.....	-----	75	-----	9.3	-----	-----	-----
II.....	1	76	8.03	-----	June 13	90	Do.
	2	76	8.24	20.6	do.....	90	Do.
	3	76	8.45	20.75	do.....	90	Do.
Average for second female.....	-----	76	-----	20.67	-----	-----	-----
Average for both females.....	-----	-----	-----	13.87	-----	-----	-----

THE YOUNG LARVÆ IN THE BROOD CHAMBER.

In the orchard the larvæ appear in the brood chambers from 1 to 3 days before any of them emerge. During the time of maximum emergence most of the larvæ remain in the brood chamber only until the day following birth. If larvæ are removed from the brood chamber by overturning the scales they migrate at once to the leaves. Even those that have been born but a few hours do this. The maximum time during which they can remain in the brood chamber depends upon their ability to live without food. Experiments indicate that 4 days is the maximum limit of life for unemerged larvæ.

After periods of unfavorable weather lasting from 3 to 5 days dead young are always found in the brood chambers. Unfavorable weather up to 3 days duration does not seem to have an unfavorable effect upon the unemerged larvæ.

EMERGENCE.

Unless weather conditions interfere, the emergence starts upon the second day after the young appear in the brood chambers.

In 1912 a scattered emergence started in the orchard at Mont Alto, Pa., on June 8, with the first young in the brood chambers on June 6. These specimens showed the regular two-day interval between birth and emergence. The regular emergence did not start until a week later.

Emergence from 26 isolated females started June 16, and gave its daily maximum on June 18. Upon June 25, 50 per cent had emerged, and 75 per cent had emerged July 1. Emergence from these scales ceased July 17, after 4,273 had emerged. Twenty-nine specimens in all were isolated at the start of the foregoing experiment. Data from all these are included in Table VII. Specimens numbered 12, 16, and 23 were so manifestly abnormal that they were omitted in calculating the foregoing percentages.

TABLE VII.—Record of 29 isolated females of the terrapin scale during the emergence period of 1912, at Mont Alto, Pa.

No.	Total emergence.	Last larva emerged.	Scale loose.	Scale dropped.	Scale taken.	Embryos by dissection.	Number dead embryos.
1.....	142	July 8	July 12	.....	July 12	451	One-third.
2.....	121	July 3	July 4	.....	July 5	0	All.
3.....	189	July 9	.....	.....	July 15	60	Most.
4.....	214	July 3	.....	.....	July 3	204	Do.
5.....	245	July 15	.....	.....	July 15	218	Do.
6.....	189	July 13	July 8	.....	do.....	192	Do.
7.....	152	June 26	.....	June 26	.....	.....	.....
8.....	137	July 7	July 10	.....	July 10	37	Do.
9.....	119	July 15	.....	.....	July 15	150	All.
10.....	143	June 27	.....	June 30	.....	.....	.....
11.....	303	July 7	July 12	.....	July 12	326	One-fourth.
12.....	3	June 21	.....	June 24	.....	.....	.....
13.....	146	July 2	.....	July 3	.....	.....	.....
14.....	88	July 8	July 11	.....	July 11	8	All.
15.....	220	July 12	.....	.....	July 15	195	Most.
16.....	11	June 24	.....	July 7	.....	.....	.....
17.....	124	July 15	.....	.....	July 15	97	All.
18.....	168	do.....	.....	.....	do.....	138	Do.
19.....	71	June 24	.....	June 25	.....	.....	.....
20.....	187	July 15	.....	.....	July 15	22	Do.
21.....	349	July 12	.....	.....	do.....	193	Do.
22.....	45	July 15	.....	.....	do.....	24	Do.
23 ¹	1	June 22	.....	June 25	.....	.....	.....
24.....	42	July 8	July 8	.....	July 8	145	Do.
25.....	291	July 6	July 6	.....	July 6	343	Do.
26.....	144	July 11	.....	July 12	.....	.....	.....
27.....	151	July 6	July 11	.....	July 11	359	Most.
28.....	153	July 15	.....	.....	July 15	148	Do.
29.....	125	July 8	July 11	.....	July 11	73	Do.
Total.....	4,273	.....	.....	.....	.....	3,383	.....

¹ Larva of *Hyperaspis binotata* emerged June 24.

Total embryos, 7,656.

Table VII gives, in summary, the history of the isolated scales used in 1912. It shows the ratio between the number of emerged larvæ and the total number of embryos produced, but it does not show the date of exhaustion of all the scales.

Table VIII gives the detailed emergence of larvæ for 29 isolated females from June 16 to July 15, 1912. At the latter date the scales were nearly all exhausted and 18 of them had dropped. Only 9 were able to produce young at the time of removal. The total number emerging was 4,273. Scale No. 21 gave 349, the highest number of larvæ produced by any of these scales.

TABLE VIII.—*Daily emergence of larvæ from the 29 isolated females of the terrapin scale in Table VII, Mont Alto, Pa., 1912.*

No.	June, 1912.															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1.			1	37		4				3	1	3	1			
2.			1			21		14	1	6	10	20	14	17	1	
3.						4		7	6	28	8	20	17	26	1	
4.				33		33	3	20	25	4	3	9	11	26	24	8
5.				22		21	6	16	9	12	7	30	14	16	12	3
6.			1	2		8	3	24	18	17	10	12	13	29	3	
7 ¹ .		2	4	37		34	7	2	19	44	6	6				
8.		3	4	44		7	4	13	13	5	5	8	6	18	1	
9.						8	5	4	8	7	15	20	6	12	1	
10.						30	12	6	5	4	7	14	3			
11.		2	3	110		45	18	15	10	9	12	24	9	24	1	
12.						1	2									
13.			2	50		46	9	10		16	3	5	3	1		
14.				5		9	3		11	20	12	20	5			
15.						39	11	16		9	8	14	14		3	
16.			1					2		4						
17.							1		4	4						
18.			1	6			7	8	11	11	15	26	10	21	2	
19.						15	13	11	5	27		8	20	13	10	2
20.			1				4	8	3	9	6	12	6	14	2	
21.		2	4	80		48	22	26	19	9	18	20	13	14		
22.										1			1			
23 ² .								1								
24 ³ .								4		8	1	2	8			
25 ⁴ .			1	32	2	32	11	39	19	24	15	20	13	24	10	2
26.						1			1		1	2	7	4	7	
27.				14		16	8	15	5	9	7	15	25			
28.						14			15	6	8	16	11	19	3	1
29.											8	30	6	30	10	5
Total.		9	24	534	2	421	164	261	202	296	194	368	229	295	91	21

¹ Dropped June 26.

² *Hyperaspis binotata* larva emerged June 24; scale dropped June 25.

³ Loose and removed for dissection July 8.

⁴ Loose and removed for dissection July 6.

TABLE VIII.—Daily emergency of larvæ from the 29 isolated females of the terrapin scale in Table VII, Mont Alto, Pa., 1912—Continued.

No.	July, 1912.															Total.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1.....	30	14	11	9	.....	19	3	6	.....	.....	.....	.....	.....	.....	.....	142
2.....	2	10	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	121
3.....	33	14	2	2	1	1	.....	11	3	.....	.....	.....	.....	.....	5	189
4.....	7	1	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	214
5.....	21	3	6	10	.....	8	1	11	3	5	.....	.....	.....	.....	8	245
6.....	23	2	5	3	.....	7	3	4	1	.....	.....	.....	1	.....	.....	189
7 ¹.....	.....	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	152
8.....	.....	2	.....	.....	.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	137
9.....	9	4	2	3	.....	8	.....	7	.....	1	.....	.....	.....	.....	1	119
10.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	143
11.....	6	5	.....	2	.....	6	2	.....	.....	.....	.....	.....	.....	.....	.....	303
12.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3
13.....	.....	1	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	146
14.....	.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	88
15.....	43	14	5	10	.....	9	3	9	4	2	4	2	.....	.....	1	220
16.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11
17.....	28	6	5	2	.....	3	5	9	.....	1	1	.....	.....	.....	2	124
18.....	17	7	4	2	.....	7	1	3	2	.....	2	.....	2	.....	3	168
19.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	71
20.....	36	17	3	9	.....	24	5	7	7	4	3	4	.....	.....	3	187
21.....	28	11	5	5	1	3	.....	11	6	.....	3	1	.....	.....	.....	349
22.....	2	3	.....	3	.....	9	11	6	4	.....	2	.....	.....	.....	3	45
23 ².....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
24.....	2	.....	.....	.....	.....	.....	.....	17	.....	.....	.....	.....	.....	.....	.....	42
25 ⁴	13	4	2	4	19	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	292
26.....	31	12	5	15	.....	13	9	21	8	5	2	.....	.....	.....	.....	144
27.....	23	3	4	4	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	151
28.....	7	14	3	2	.....	6	3	7	4	2	3	4	.....	.....	5	153
29.....	19	6	4	3	.....	2	.....	2	.....	.....	.....	.....	.....	.....	.....	125
Total.....	380	155	77	88	21	134	48	132	42	20	21	11	3	.....	31	4,273

¹ Dropped June 26.² *Hyperaspis binotata* larva emerged June 24; scale dropped June 25.³ Loose and removed for dissection July 8.⁴ Loose and removed for dissection July 6.

The weather was abnormal during the emergence period of 1912. It was very cold, with a daily maximum below 70° F. from June 13 to 15, inclusive. June 19 was rainy and cold, with the daily maximum below 60° F. The daily maximum did not go above 70° until June 22, when it rained. From June 24 to 28, inclusive, the weather was favorable, except for local showers on June 25 and 27. June 29 and 30 were unfavorable, due to a cold rain and no sun. July 5 also was a rainy day. The only favorable weather was from July 6 to 11, inclusive, but it was too late to have an appreciable effect.

The dotted curve on the following emergence graph, figure 2, shows clearly the effect of these weather conditions. The solid line shows the curve as it would probably be in favorable weather.

During 1913 a few larvæ appeared in the brood chambers at Mont Alto, Pa., on June 11. The larvæ were quite abundant in the brood chambers on June 12, and emergence started June 13. Thus the interval between first birth and first emergence was 2 days. The emergence from the isolated scales also started June 13 and the maximum daily emergence was June 18. Fifty per cent and the 75

per cent of emergence came upon June 23 and June 30, respectively. Emergence ceased September 30, after 12,336 larvæ had emerged.

Table IX gives an individual record of the scales observed in 1913, showing the date of exhaustion. It also shows the effect of the

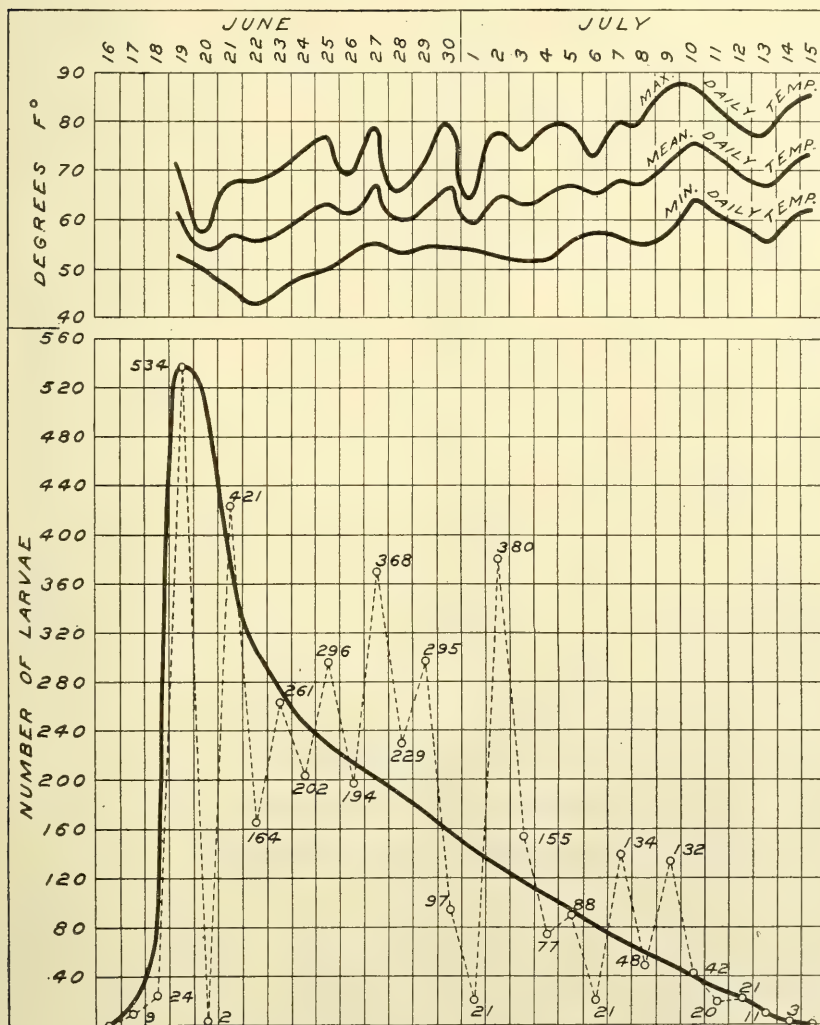


FIG. 2.—Emergence curve for the first 28 days of emergence of the terrapin scale, Mont Alto, Pa., 1912. (Original.)

attack of Hymenoptera and the effect of the predacious beetle *Hyperaspis binotata* Say, but does not show the total number of embryos.

TABLE IX.—*The emergence from 41 isolated females of the terrapin scale during the emergence period of 1913, Mont Alto, Pa.*

No.	Total larvæ.	Last larva emerged.	Parent scale turned black.	Knocked off by accident.	Scale loosened.	Scale dropped.	Scale dead.
1.....	204	July 14	.....	.....	.....	.....	July 14
2.....	76	July 1	.....	.....	.....	July 21	July 21
3.....	494	Aug. 7	.....	Aug. 27	.....	.....	.....
4.....	206	July 4	.....	.....	July 4	July 4	July 11
5.....	209	June 29	.....	.....	.....	July 10	June 30
6.....	233	Aug. 30	Sept. 5	.....	.....	Sept. 30	Sept. 1
7.....	421	Aug. 26	do	.....	.....	Sept. 2	Aug. 28
8.....	708	Sept. 19	.....	.....	.....	Sept. 30	Sept. 20
9.....	458	July 20	.....	.....	.....	Aug. 15	July 2
10.....	796	Aug. 30	.....	Sept. 2	Sept. 1	Sept. 2	.....
11 ¹	245	June 30	.....	.....	.....	July 31	July 1
12.....	663	Sept. 30	.....	.....	.....	Oct. 11	Oct. 11
13 ²	221	July 7	.....	.....	.....	Aug. 1	July 8
14.....	165	June 28	.....	.....	June 22	June 28	June 28
15.....	53	June 22	.....	June 22	do.	.....	.....
16 ³	387	July 21	.....	.....	.....	.....	Aug. 7
17 ⁴	389	July 7	.....	.....	.....	Aug. 1	Aug. 1
18 ⁵	192	July 2	.....	.....	.....	July 18	July 18
19.....	174	June 29	.....	.....	.....	July 1	July 1
20 ^{6,7}	94	June 24	June 15	.....	.....	July 21	June 22
21 ⁸	394	July 5	.....	.....	.....	July 18	July 18
22.....	130	do.	.....	.....	.....	July 11	July 6
23.....	240	July 6	.....	.....	.....	July 18	July 7
24.....	114	June 20	.....	June 22	.....	.....	.....
25.....	9	June 19	.....	.....	June 21	June 22	June 22
26.....	389	July 10	.....	.....	.....	July 11	July 11
27.....	267	June 28	.....	.....	.....	June 29	June 29
28.....	654	Aug. 18	.....	Aug. 23	.....	.....	.....
29 ⁹	472	Aug. 14	.....	.....	.....	.....	Aug. 27
30.....	309	Aug. 1	.....	.....	.....	Oct. 11	Aug. 2
31 ¹⁰	196	July 3	.....	.....	.....	Aug. 18	Aug. 1
32.....	42	June 29	.....	.....	.....	July 1	July 1
33.....	76	July 2	.....	.....	.....	.....	July 3
34.....	121	June 23	.....	June 23	.....	.....	.....
35.....	98	June 28	.....	.....	.....	June 28	June 28
36.....	464	Aug. 7	.....	.....	.....	.....	Aug. 27
37.....	373	July 14	.....	.....	.....	.....	July 15
38.....	433	July 26	.....	.....	.....	Aug. 11	Aug. 11
39.....	391	July 6	.....	.....	.....	Aug. 18	July 17
40.....	657	Sept. 19	.....	.....	.....	.....	Sept. 20
41.....	119	July 21	.....	.....	.....	Aug. 23	July 22
Total.....	12,336	.....	.....	.....	.....	.....	.....

¹ First instar *Hyperaspis binotata* emerged from this scale July 1.² First instar *Hyperaspis binotata* emerged from this scale July 14.³ One hymenopterous parasite (*Coccophagus* sp.) emerged from this scale Aug. 7.⁴ Two hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 16.⁵ Seven hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 13.⁶ First instar *Hyperaspis binotata* emerged from this scale July 5.⁷ Three hymenopterous parasites (*Coccophagus* sp.) emerged from this scale July 13.⁸ Second instar *Hyperaspis binotata* emerged from this scale July 18.⁹ First instar *Hyperaspis binotata* emerged from this scale July 18.¹⁰ First instar *Hyperaspis binotata* emerged from this scale June 30.

The emergence started June 13 with 18 larvæ; the maximum daily emergence occurred upon June 18, when 1,229 larvæ emerged. This was 5 days after emergence had started. The first half of the brood (6,168 larvæ) completed its emergence upon June 23. This was the tenth day of emergence. Seventy-five per cent of the brood (9,250 larvæ) had emerged by June 30. This was upon the seventeenth day of emergence. The daily emergence was not taken for the entire period of 1913, but data for the first 22 days, which cover slightly more than three-fourths of the total emergence, are given in Table X.

Table XI supplements Table X. It carries the emergence through the entire period by weeks. It also gives the date of the end of emergence for each of the parent scales.

TABLE XI.—Weekly emergence from the 41 isolated females of the terrapin scale in Table IX, Mont Alto, Pa.

No.	Total larvæ.	June 13-19.	June 20-26.	June 27- July 3.	July 4-10.	July 11-17.	July 18-24.	July 25-31.	Aug. 1-7.	Aug. 8-14.	Aug. 15-21.	Aug. 22-28.	Aug. 29- Sept. 4.	Sept. 5-11.	Sept. 12-18.	Sept. 19-25.	Sept. 26- Oct. 2.	Emer- gence ended.
1.	204	65	86	42	0	11	6											July 14
2.	76	36	36	27	0	0	0											July 1
3.	494	94	205	69	18	25	20	32	31									Aug. 7
4.	206	36	110	56	4													Aug. 4
5.	209	64	105	40														June 29
6.	233	21	76	32	18	26	29	20	6	3	0	1	1					Aug. 30
7.	421	136	136	45	37	50	40	3	1	2		1						Aug. 26
8.	708	117	151	108	20	40	34	51	21	50	48	13	41	12	1	1		Sept. 19
9.	458	191	177	55	22	12												July 21
10.	796	80	152	109	31	33	67	86	79	50	77	21	11					Aug. 30
11.	245	66	157	22														June 30
12.	663	170	147	69	13	33	61	56	13	38	26	8	13	8	5		3	Sept. 30
13.	221	146	59	14	2													July 7
14.	165	81	82	2														July 7
15.	53	39	14															June 28
16.	387	88	189	14														June 22
17.	389	96	243	67	8	23	12											July 21
18.	192	65	96	31	2													July 7
19.	174	32	59	83														July 2
20.	94	37	57															June 29
21.	394	53	219	117	5													June 24
22.	130	62	48	15	5													June 24
23.	240	83	114	39	4													July 5
24.	114	77	37															Do.
25.	9																	July 6
26.	389	148	153	72	16													June 20
27.	267	76	176	15														June 19
28.	654	114	184	139	33	16	89	34	27	11	7							June 10
29.	472	44	190	58	41	22	54	25	25	13								June 28
30.	309	36	190	65	4	1	12	0	1									Aug. 18
31.	196	47	114	35														Aug. 14
32.	42	4	32	6														Aug. 1
33.	76	0	47	29														July 3
34.	121	71	50															June 2
35.	98	13	74	11														July 2
36.	464	67	95	116	15	19	63	62	27									June 28
37.	373	138	187	26	18	4												Aug. 7
38.	433	102	209	59	13	16	33	1										July 14
39.	391	109	221	54	6	0	0	0	1									July 26
40.	657	70	178	41	25	39	38	17	45	42	41	46	41	24	9	1		July 6
41.	119	40	59	15	1	3	1											Sept. 19
Total.....	12,336	2,961	4,914	1,831	361	373	560	387	277	209	199	90	107	44	15	2	3	July 21

Table XII gives a summary of these data, with some additional details from Tables VII and IX. It also compares 13 normal females from each isolation.

TABLE XII.—A summary of the emergence data from Tables VII, VIII, IX, X, and XI.

No.	Year.	Number of females.	Number of larvæ emerged.	Average number per female.	Emergence started.	Maximum daily emergence.	Emergence, 50 per cent.	Emergence, 75 per cent.	Emergence, 100 per cent.
1	1912	Total 26... Normal 13.	4,258 2,753	163.7 211.8	June 16 do.	June 18 do.	June 25 do.	July 1 do.	July 15 Do.
2	1913	Total 41... Normal 13.	12,336 5,211	297.95 400.8	June 13 do.	do. do.	June 23 June 24	June 29 July 10	Sept. 30 Do.

¹ All females on twigs were dissected July 15. The isolated females in 1912 had all stopped producing young by July 15.

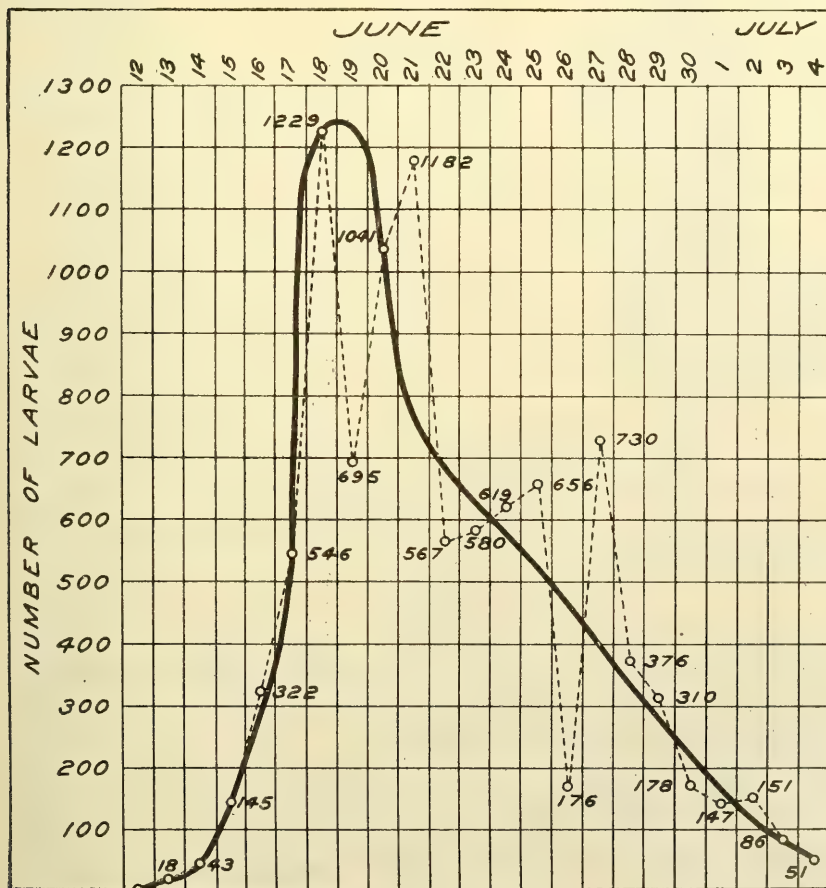


FIG. 3.—Emergence curve for the terrapin scale; first 22 days of emergence, June 13 to July 4, inclusive, Mont Alto, Pa., 1913. (Original.)

The 1912 emergence was shortened by the drying of the twigs to which the females were attached. This was due to the method of isolation. This difficulty was overcome in the 1913 record.

The larvæ of *Hyperaspis binotata* Say were more destructive in 1913 than in 1912, but on the whole both records are very true to the conditions prevailing in the orchard during the respective seasons.

For convenience in comparison and also to show the effect of weather conditions upon this emergence, two graphs, figures 3 and 4,

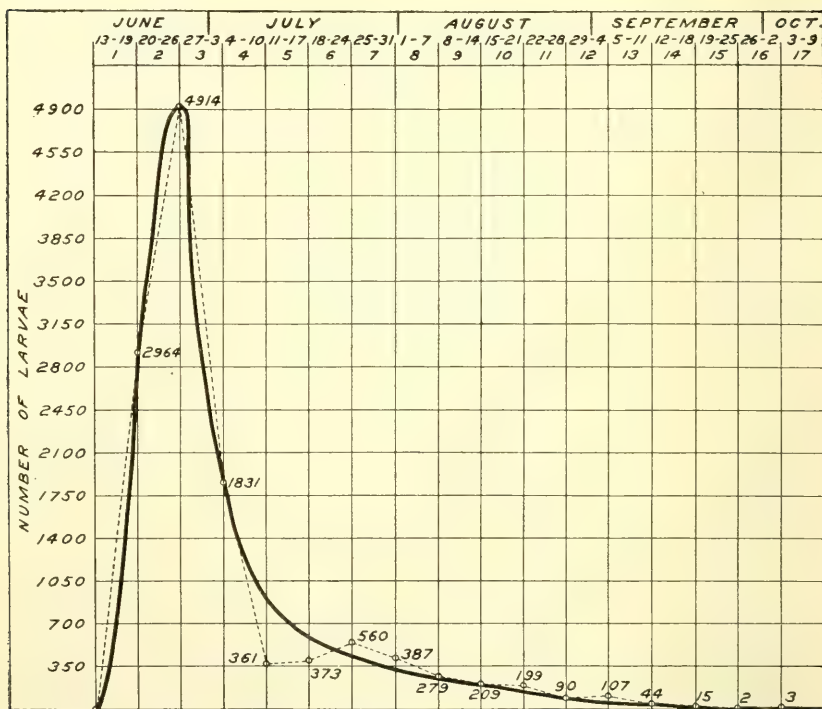


FIG. 4.—Curve of the leafward migration of the terrapin scale for the total emergence period of 1913. (Original.)

are appended. Figure 3 has a solid line added. This represents the weather correction for the curve. In figure 4, where the curve is determined from weekly observations, very little irregularity, due to the daily weather conditions, appears.

The emergence period of 1913 was moderately favorable. The temperature was high and the storms were of short duration. On June 19, 22, and 26 rain checked the emergence, but the larvæ merely remained in the brood chambers over night and emerged on the following day.

The graph of total emergence by weeks during 1913 (fig. 4) shows a very uniform curve. From the graph it appears that the major portion of the young emerged during the first three weeks of the period.

LEAFWARD MIGRATION.

The migration to the leaves begins immediately after emergence. The larvæ start emerging usually about 10 a. m., or even earlier if the temperature is high, and by 3 p. m. the daily migration has nearly ceased. At Mont Alto, Pa., during the noon hours of June 15 to 20, the branches of infested trees were swarming with countless numbers of migrating larvæ. During the leafward migration the larvæ are strongly phototropic and negatively geotropic. The time required for an individual to make this migration and to take its position upon the leaf is remarkably short.

Two hours is about the average time from emergence to the completion of the migration. Many reach the leaves and attach in less than an hour, but others, especially those that have ascended dead branches, may continue to move about for several days if a suitable leaf is not found sooner.

It is very unusual for the larvæ to relocate when they have once taken position upon a leaf, though they do this when the leaf loses its vigor. The larvæ, except in rare and unusual cases, attach to the underside of the leaves, mostly alongside and parallel to the midrib, or the larger veins. (Fig. 5.)

Larvæ usually attach to the first available leaves. The basal leaves upon an infested branch are always more heavily infested than those farther up. A sticky secretion upon the very young leaves repels the young larvæ and prevents them from attaching. The wooly coat of the fruit protects it from larvæ. Larvæ frequently crowd upon the fruit, but in their struggles to free themselves from the fuzz they invariably fall to the ground.

The rate of migration varies with the temperature and the surface upon which the larvæ are placed. Table XIII gives the rate per hour, time, temperature, and the distance traveled by five migrating larvæ of the first instar upon smoked wrapping paper. The average temperature in this experiment was very favorable, being 87° F. The rate per hour was very low, owing to the annoyance caused



FIG. 5.—Peach leaf with attached larvæ of the terrapin scale. (Original.)

the larvæ by the fine soot deposit upon the smoked paper. The distance traveled varied from 97.7 cm. to 175.8 cm. Figure 6 shows a tracing made by four of the above-mentioned larvæ.

TABLE XIII.—*Record of travel of five first-instar terrapin-scale larvæ on smoked paper, Oct. 9, 1912, Mont Alto, Pa.*

No.	Start.	End.	Time.	Distance.	Rate per hour.	Average temperature.
			Hrs. Min.	Cm.	Cm.	° F.
1.....	9.26 a. m.	2 p. m.	4 34	113.7	26.54	87
2.....	9.26 a. m.	3.15 p. m.	5 49	175.8	26.596	86
3.....	11.20 a. m.	2 p. m.	2 40	97.7	36.64	89
4.....	10.08 a. m.	2 p. m.	3 52	99.6	25.76	87
5.....	9.26 a. m.	2.50 p. m.	5 24	161.7	29.94	86.7
Average.....					29.095	87

The larvæ are so small that they leave no trace when moving over the finest soot deposit. The deposit, moreover, retards them. In moving they are constantly exploring the surface with their antennæ, and these soon become coated with soot particles. When this happens the insect halts until the antennæ are cleaned. (For comparison with the rate of progress upon smooth, unsmoked paper, see Table XIV.)

A single larva that emerged at 12.10 p. m traveled, when placed upon plain wrapping paper, 826 cm. during the 3 hours and 20 minutes in which it was under observation. This larva traveled constantly after the first interval, and its speed was about eight times that of larvæ on sooted paper. Figure 7 shows a tracing made of this larva.

TABLE XIV.—*Record of the travel of a newly emerged larva of the terrapin scale on plain wrapping paper, July 10, 1912, Mont Alto, Pa.*

Time of observation.	Temperature.	Total distance.	Interval distance.	Rate per hour.	Average temperature.
	° F.	Cm.	Cm.	Cm.	° F.
12.10 p. m.	86				
12.25 p. m.	86	35.3	35.3	141.2	86
1 p. m.	86	184.4	149.1	255.6	86
1.15 p. m.	86	239.3	44.9	179.6	86
1.30 p. m.	86	298.3	59	236	86
2.10 p. m.	87.5	473.4	175.1	262.65	86.75
2.30 p. m.	87.5	557.2	83.8	251.4	87.75
3.30 p. m.	88	826	188	282	88
Average.....				231.356	86.9

In 1912 three experiments were performed to determine the longevity of the leafward migrants when they were unable to reach the leaves. The data from these experiments are recorded in Table XV, and summarized in Tables XVI and XVII. They show that

the migrating larvæ can live from 2 to 3 days. More than 78 per cent of the larvæ died upon the second day, and the mortality of the remainder was about equally divided between the first and third day. It was apparent that the third day was of very little value to the larvæ as they were in a state of collapse.

TABLE XV.—*Longevity of larvæ of the terrapin scale at the leafward migration.*

Experiment No.	Number of larvæ used.	Time of start.	Time of finish.	Surface.	Time of observation.	Number of larvæ dead.
I.....	3	July 2, 9 a. m..	July 4, 1 p. m..	Dead peach twig..	July 2, 9 a. m.	0
					July 3, 9 a. m.	0
					July 4, 9 a. m.	2
					July 4, 1 p. m.	3
II.....	125	July 7, 12 noon.	July 10, 3.30 p. m.	Exterior surface of test tube over water.	July 7, 12 noon.....	0
					July 8, 8 a. m.	10
					July 9, 7.30 a. m.	108
					July 9, 12 noon.....	110
					July 10, 8 a. m.	122
					July 10, 3.30 p. m.	125
III.....	13	July 4, 8.30 a. m.	July 6, 8.30 a. m..	Inner surface of test tube over water.	July 4, 8.30 a. m.	0
					July 4, 3 p. m.	0
					July 5, 8.30 a. m.	5
					July 5, 4 p. m.	7
					July 5, 9 p. m.	7
					July 6, 8.30 a. m.	13

TABLE XVI.—*Daily mortality of larvæ of the terrapin scale from data in Table XV.*

Day of death.	Experiment I.	Experiment II.	Experiment III.	Dead, by days.	Per cent dead, by days.
First.....	0	10	5	15	10.63
Second.....	2	100	8	110	78.01
Third.....	1	15	0	16	11.34
Total.....	3	125	13	141	99.98

The summary in Table XVII shows that the average longevity for the three experiments was 2 days 9½ hours and the maximum longevity 3 days.

TABLE XVII.—*Maximum longevity of migrating larvæ of the terrapin scale from experiments given in Table XV.*

Experiment.	Number of specimens.	Longest life.
I.....	3	2 days 4 hours.
II.....	125	3 days.
III.....	13	2 days.
Average.....		2 days 9½ hours.

THE LEAFWARD MIGRATION AS A FACTOR IN THE SPREAD OF THE TERRAPIN SCALE.

The leafward migration is a strong element in the spread of the scale over the branches of infested trees, but it is not directly effective in spreading it from tree to tree unless the trees are in actual contact.

Indirectly it is one of the strongest factors in the spread of the scale. The young larvæ are not readily displaced by wind, but

they sometimes drop purposely from dead twigs, especially when they have reached the tips without finding foliage. Such larvæ may fall upon foliage lower down or drift in air currents to foliage on adjacent trees. Most of them, however, perish on the ground. During windy days particles of bark and loosened leaves are carried by the wind. That wind is a prominent factor in the local spread is indicated by the fact that infestations travel through orchards in the direction of the prevailing wind. Thunderstorms sometimes come so suddenly that the young migrants are washed from the twigs before they have reached the leaves. This seldom happens, because the young do not ordinarily emerge when the humidity is high. The migrants, when displaced by rain, will float for some distance, especially if accompanied by particles of bark or other débris.

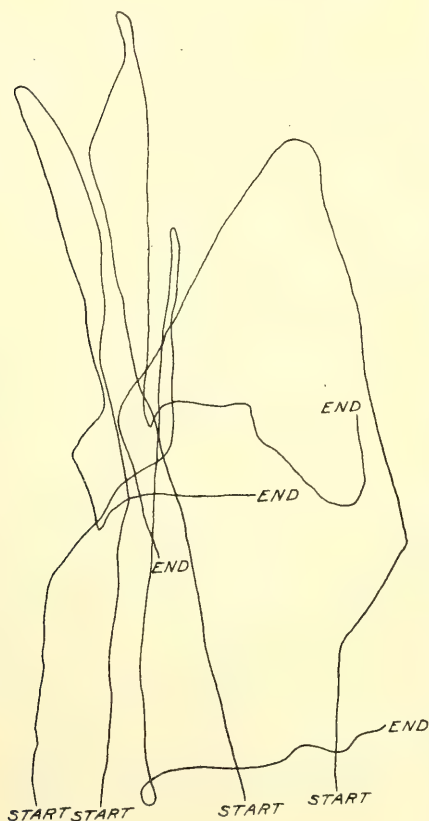


FIG. 6.—Tracing of four young terrapin scales during the leafward migration. Reduced 8 times. Temperature, 87° F. Average rate per hour, 29.095 cm. (Original.)

larvæ cling readily to hairs, to feathers, and to other small objects. While the author has never taken insects with the larvæ attached, he has placed specimens of *Brochymena* upon branches covered with migrating young, with the result that the larvæ were soon clinging to their legs. Feathers touched lightly to the same branches were clasped by the moving young. A pair of cloth gloves placed for 10 minutes upon a branch had 20 larvæ upon them when removed. This last observation indi-

The spread, except as indicated, requires the aid of some transporting agent. The migrating

icates that orchard workers during the migrating period might unwittingly aid in the dispersal of this pest.

It is possible for larvæ of the first instar which have attached themselves to leaves to be transferred to other trees, as the following experiment shows. Thirty larvæ that had loosened themselves from a wilting leaf were placed on the foliage of another tree July 22 at 2 p. m. The first of these was found attached July 23 at 8 a. m., and all of them were attached by July 24 at 8 a. m.

Dispersal may occur at this period in at least four ways:

(1) By dropping of larvæ from dead branches, fruit, etc.

(2) By wind transportation.

(3) Through transportation by storm water.

(4) By animate agents (insects, birds, orchard workers, etc.).

MORTALITY DURING MIGRATION.

Practically all of the emerged young make a successful migration. The only exceptions are in cases where the larvæ stray upon dead branches or the fruit and are unable to return and in the case of those destroyed by the occasional attacks of predatory enemies. The mortality at this time is indicated by the small number of larvæ that fail to attach themselves to the leaves. Of the 12,336 larvæ that migrated in 1913 from the isolated scales, all but 15 successfully attached to the underside of leaves. The mortality upon the average orchard tree is slightly higher than is shown in the case of these isolated larvæ.

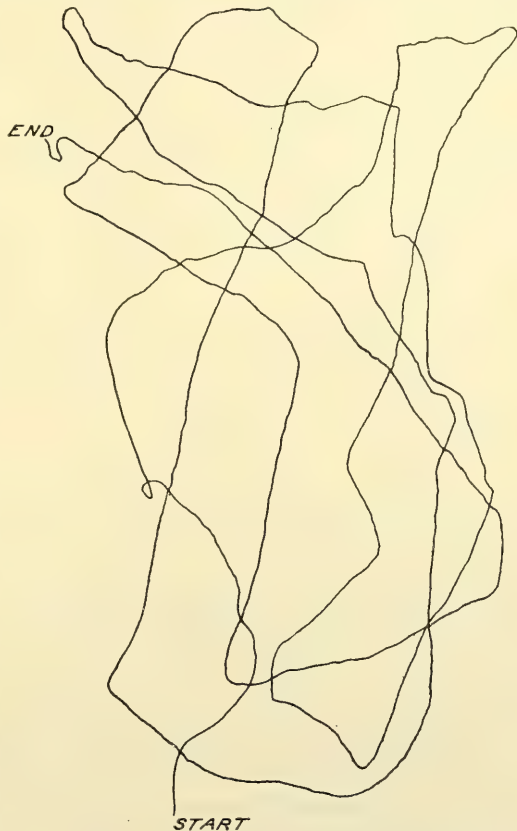


FIG. 7.—Tracings of a young terrapin scale for the first 3 hours and 20 minutes of the leafward migration. Reduced 8 times. Temperature, 86.90° F. (Original.)

SIZE OF THE LARVÆ AT TIME OF MIGRATION.

The size of the larvæ varies. Strong females produce larger young than weak ones. The larvæ are largest at the beginning of reproduction. They gradually become smaller as the season advances. Measurements made in June, 1913, of 10 larvæ give the following results: Length, maximum 0.475 mm., minimum 0.41 mm., average 44 mm.; width, maximum 0.26 mm., minimum 0.20 mm., average 0.23 mm.

DESCRIPTION OF THE MIGRATING LARVÆ.

The distinguishing characteristics of the leaf migrant are: Average length, 0.43 mm.; average width, 0.23 mm.; color, pale translucent yellow, with reddish brown eye-spots; body very flat and oblong; antennæ with six joints; feeding tube internal and folded midway upon itself. (Pl. I, fig. 2, p. 8.) The anal plates have each a single major apical seta 0.2 mm. in length. The plates have their distal ends just reaching to the tips of the body lobes. These plates are held in a relaxed position, that is, with their adjacent edges forming an acute angle. The terminal anal plates, together with the folded feeding tube, are reliable characters for identifying the leafward migrant.

LEAF-ATTACHED LARVÆ, FIRST INSTAR.

The larvæ emerge, make their migration, and attach to the leaves during the second day after birth, but take no food until after attaching to the leaf. Death by starvation and exhaustion results during the third day after emerging provided an attachment is not made. It is doubtful whether the larvæ can live in the brood chamber more than 4 or 5 days, and at any rate they would be too weak after the fourth day to make an effectual effort to reach the leaves. In 1912 there were several periods in which it was cool and wet for four successive days. After these periods many dead larvæ were found in the brood chambers, some chambers becoming so clogged as to prevent the further escape of young.

The larva, after attaching to the underside of the leaf, retains in the main its earlier characteristics. The proboscis is thrust into the leaf tissues. The anal plates, which during the migration were carried with their adjacent edges diverging, are now held in close contact when in repose. The body lobes, which at attachment were even with the tips of the anal plates, grow steadily backward and inward until they meet behind the anal plates. By this growth the anal plates with their long setæ are made to recede from the posterior edge to a position upon the dorsal surface, as shown in Plate I, figure 3, *a*, *b*, p. 8. A thin, brittle covering of wax appears on the dorsal surface of the larvæ during the latter part of the first instar. All leaf-attached

larvæ that have their anal plates adorned with major apical setæ are in the first instar.

The growth is constant. Both length and width increase in the same ratio. In the first instar the larvæ increase their length and width about two and one-half times, but they do not noticeably increase their height. Tables XVIII and XIX show the measurements for a total of 201 larvæ at various ages during the first instar. The data in Table XVIII are from larvæ that emerged late in the season of 1912. They encountered more than the usual amount of unfavorable weather. The data in Table XIX are from larvæ that emerged in July, 1913, and that had favorable conditions. This table also shows the percentages in the first and second instars at various ages. It required about 25 days for larvæ emerging on August 9, 1912, to reach their full development (0.9 to 1 mm. long) and to molt for the first time, while those emerging July 1, 1913, reached this stage on the sixteenth and seventeenth days.

TABLE XVIII.—*Measurements of 91 first-instar larvæ during the unfavorable season of 1912, Mont Alto, Pa.*

No.	Age.	Number of specimens.	Average length.	Average width.	Emerged—
	<i>Days.</i>		<i>Mm.</i>	<i>Mm.</i>	
1.....	0.25	6	0.44	0.23	Aug. 9
2.....	5	5	.5325	.2044	Do.
3.....	6	3	.555	.287	Do.
4.....	7	2	.6046	.276	Do.
5.....	9	14	.6307	.279	Do.
6.....	12	6	.8467	.425	Do.
7.....	15	24	.8968	.439	Do.
8.....	21	12	.931	.50	Do.
9.....	22	7	.9348	.499	Do.
10.....	25	12	.999	.522	Do.
Total.....		91			

TABLE XIX.—*Measurements of 110 first-instar larvæ during the favorable season of 1913, and the percentages of larvæ on the trees in the first and second instars.*

No.	Age.	Number of specimens.	Average length.	Average width.	Emerged—	Per cent of larvæ in first instar.	Per cent of larvæ in second instar.
	<i>Days.</i>		<i>Mm.</i>	<i>Mm.</i>			
1.....	3	22	0.5176	0.2659	July 17	100	.....
2.....	5	21	.555	.2873	do	100	.....
3.....	8	15	.7275	.39	July 1	100	.....
4.....	15	19	.94725	.5235	do	100	.....
5.....	17	8	.9625	.521875	do	80	20
6.....	18	10	.9975	.525	do	48	52
7.....	19	5	.97	.52	do	20	80
8.....	20	3	.9375	.525	June 26	10.9	89.1
9.....	21	3	.9916	.5416	July 1	7	93
10.....	22	3	.925	.525	June 24	10.7	89.3
11.....	23	1	.975	.55	June 26	3.2	96.8
12.....	24				July 1		100
Total.....		110					

The second column in each table gives the age in days. This is calculated from the time the larvæ left the brood chamber. The sixth column gives the date upon which the specimens emerged. There are added to Table XIX two columns of data to show the percentages of larvæ in the first instar and second instar at different ages. An examination of these columns will show that 50 per cent of the larvæ had passed from the first to the second instar upon the

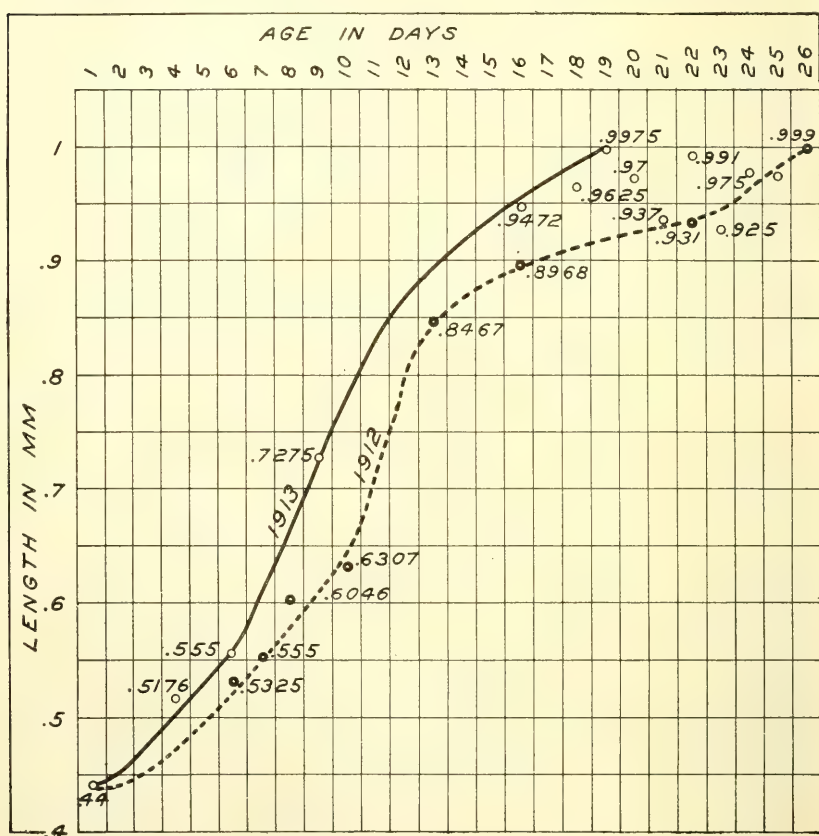


FIG. 8.—Growth curves for the first instar of the terrapin scale. (Original.)

eighteenth day, and that all had left the first instar by the twenty-fourth day. Eighteen days is the normal time spent in the first instar by larvæ during favorable seasons. Figure 8 shows the deflection of the growth curve for larvæ in the first instar which resulted from the late emergence during the unfavorable season of 1912, as compared with the curve for the favorable season of 1913. These curves are derived from the data in Tables XVIII and XIX. The curves are similar, but the broken curve shows clearly the effect of unfavorable weather in 1912 at both the beginning and the end of the instar.

LENGTH OF THE FIRST INSTAR.

The earliest molts were upon the sixteenth day and were observed during the very favorable weather of June and July, 1913. Eighteen days is the average length of the first instar at Mont Alto during favorable years, as shown in Table XVIII, columns 7 and 8. This time may be nearly doubled by unfavorable weather. Honeydew is excreted during this instar, but in very small quantities, and is of no economic importance.

DISPERSAL OF FIRST-INSTAR LARVÆ BY LEAVES.

It is probable that this species is dispersed to some extent by the transportation of larvæ upon wind-borne leaves during storms. An experiment performed July 22, 1913, showed that first-instar larvæ can loosen from slowly drying leaves and that they can move about and reattach to living foliage, so that if infested leaves should lodge in adjacent trees the latter would undoubtedly become infested.

SEXUAL DIMORPHISM IN THE FIRST INSTAR.

There are no noticeable indications of sex during this instar, except in the anal ring. It is possible in some cases to distinguish the females from the males after the fifteenth day by their increased width. At this time the length of the females is usually less than twice their width, while the length of the males is usually greater than twice their width.

Nearly all specimens are distorted by crowding, or by contact with the veins of the host (fig. 5), so that this variation in the ratio of length to width can not be depended upon for distinguishing the sexes. By dissection, however, they can be distinguished. The anal ring of the male consists of only six setæ, while the anal ring of the female consists of eight.

THE FIRST MOLT.

There is no change of position at the first molt. The skin splits along the back and is worked downward and backward underneath the body. The last portion to loosen is that about the anal plates. The major apical setæ disappear at this molt; hence the absence of these is positive evidence that the first molt has passed.

The larvæ stop growing one day before molting and become more opaque. The time required to make this molt is from 5 to 30 minutes, depending upon the weather conditions and the vigor of the larvæ. The molt is usually made in the early morning.

Observations made upon 5,000 larvæ approximately one-half of which emerged from June 24 to August 9, 1912, and the others from June 24 to July 1, 1913, show that this molt may take place as early as the sixteenth day and as late as the twenty-sixth day. The aver-

age age for this molt in 1912 was 20 days, but this period is longer than in favorable years. During the favorable season of 1913 a few specimens from the rearing of July 1 made this molt on the sixteenth day, but the largest daily molts were from the eighteenth to the twenty-second day, with the maximum molt upon the eighteenth day. It is, however, very frequently delayed. Table XX gives details of the first molt as shown by three rearings in 1913 and by data obtained in orchards in 1912. It will be noticed that in all cases molting started either upon the sixteenth or seventeenth day and that it terminated in all cases by the twenty-sixth day. The 1913 rearings all had favorable weather and would undoubtedly all have given their maximum daily molts upon the eighteenth day had it not been for a local storm on that date which retarded the natural emergence for the rearings of June 24 and June 26.

TABLE XX.—*Details of the first molt of the terrapin scale from 3 rearings in 1913 and from orchard data of 1912.*

Date larvæ emerged.	Age at starting of first molt.	Per cent molted at various days specified.							Age at maximum daily molt.
		17th.	18th.	19th.	20th.	21st.	22d.	26th.	
July 1, 1913. . .	<i>Days.</i> 16	20	52	80	-----	-----	100	-----	<i>Days.</i> 18
June 24, 1913. .	16	2	-----	-----	-----	40	85	100	22
June 26, 1913. .	16	5	20	60	90	91	100	-----	19
Orchard larvæ 1912. . .	17	-----	(1)	-----	-----	-----	-----	-----	20

¹ Blanks represent days upon which no data were taken. It was impossible to determine, under orchard conditions, the percentage of the total infestation that molted at definite ages.

LEAF-ATTACHED LARVÆ, SECOND INSTAR.

The second instar lasts in favorable weather for 18 days and usually extends from the eighteenth to the thirty-sixth day. In the orchards about Mont Alto specimens can be taken in this instar at almost any time after the middle of July. The instar is at its maximum from July 20 to August 5. This stage of development is characterized by sexual differentiation, which begins very early in the instar. The female larvæ continue to widen and tend to become circular in outline, while the males lengthen and tend to become oval.

The male secretes during this instar the characteristic puparium. This is a waxy scale which forms over the dorsal surface. It is roof-like and is held in place by elastic strands which extend from points upon its edges to the surface of the leaf. (Pl. II, *a, e*, p. 52.) It can be recognized as early as the seventh day, but it does not reach its full development until the next to the last day of the instar, at which time growth ceases and the larva shrinks, preparatory to making the second molt.

DEVELOPMENT OF THE FEMALE.

FEMALE LARVA, SECOND INSTAR.

During the second instar the females increase in length from an average of 1 mm. to an average of 1.6 mm., and in width from an average of 0.525 mm. to 1 mm., but there is very little increase in height.

Table XXI shows the average measurements of 268 females taken at frequent intervals during this instar. These females emerged from June 20 to 26, 1913; that is, during the height of the emergence period.

TABLE XXI.—Measurements of 268 female terrapin-scale larvæ of specified ages during the second instar, Mont Alto, Pa., 1913.

No.	Emerged.	No. of specimens.	Average age at time of entering the second instar.	Age when measured.	Days in second instar.	Average length.	Average width.
	1913.		Days.	Days.		Mm.	Mm.
1.....	June 26	20	19	20	1	1.054	0.558
2.....	..do.	39	19	21	2	1.076	.590
3.....	June 24	17	21	22	1	1.063	.55
4.....	June 26	30	19	23	4	1.114	.638
5.....	..do.	21	19	24	5	1.257	.676
6.....	June 24	19	22	26	4	1.431	.775
7.....	..do.	16	22	27	5	1.380	.776
8.....	..do.	7	22	30	8	1.471	.892
9.....	June 21	17	22	30	8	1.395	.713
10.....	June 20	21	22	31	9	1.504	.835
11.....	June 26	16	19	32	13	1.506	.937
12.....	June 24	20	22	33	11	1.587	.978
13.....	..do.	11	22	34	12	1.575	1.012
14.....	..do.	14	22	36	14	1.483	.966
Total.....		268					

The rate of growth is very uniform throughout the second instar, but there is a variation in size among specimens of the same age. This is instanced in lines 8 and 9. Such variations are common and are usually the result of weather conditions or of low vitality in the host. In this instar there is very little growth in height, the average height at the end of the instar being about 0.11 mm. There is no change in color. The excretion of honeydew is moderate and is unimportant. The female has but slight ability to change position and seldom moves from one position to another upon the leaf. Larvæ from withering leaves, when placed upon fresh ones, mostly fail to make a satisfactory attachment.

In an experiment, twigs, the leaves of which were infested with second-instar larvæ, were placed in water. The larvæ soon loosened and migrated to the twigs. The advanced specimens made the second molt prematurely and migrated in the third instar; the young specimens, even those less than half the normal size, migrated also, but without molting. Some of the smaller specimens would undoubtedly have reattached to fresh leaf tissue had there been any on the twigs. The others attached in the normal manner to twigs.

Table XXII shows the time spent in the second instar by larvæ at Mont Alto. The orchard data are derived from the maximum daily emergence and the maximum daily molts. These data show for the season of 1912 a variation in the length of the instar from 16 to 36 days. Most of the specimens in the orchard, from July 20 to August 5, spent 20 days in the instar, while in the rearing of July 22 two-thirds of the larvæ completed the instar in 18 days.

TABLE XXII.—*Data showing the length of the second instar of the terrapin scale from 4 rearings of larvæ at Mont Alto, Pa.*

Year.	Brood.	Emergence.	Beginning of second instar.	End of second instar.	Length of the instar.
1912....	Rearing A....	July 22	Twentieth day....	First specimen, thirty-sixth day	<i>Days.</i> 16
				Maximum number, thirty-eighth day...	18
				Last specimen, forty-ninth day.....	29
	Rearing B....	Aug. 9	Twentieth day....	First specimen, thirty-sixth day	16
				Maximum number, thirty-eighth day...	18
				Last specimen, fifty-sixth day.....	36
1913....	Rearing A....	June 24	Twenty - second day.	First specimen, thirty-fifth day	13
				Maximum number, thirty-ninth day....	17
				Last specimen, fifty-third day.....	31
	Rearing B....	June 26	Nineteenth day...	First specimen, thirty-third day.....	14
				Maximum number, thirty-seventh day..	18
				Last specimen, thirty-ninth day.....	20

In 1913 the maximum daily orchard emergence was two days earlier than in 1912. The first instar required 18 days as against 20 days for the previous year. However, when the age at the end of the second instar is considered, it appears that in both seasons the maximum numbers completed the instar upon the fortieth day.

The larvæ used in Table XXII were placed upon 1-year-old peach trees. For the date of entering the instar is given the day upon which the maximum number entered it, and the date of leaving the instar is given for the first specimen, for the last specimen, and for the maximum daily number.

The table shows that the second instar may last from 13 to 36 days and that the maximum number of specimens remain in it from 17 to 18 days; the greatest number molting upon the eighteenth day.

SECOND MOLT OF THE FEMALE.

The second molt of the female coincides with that of the male and is little more than the casting of the skin in response to growth. There is no change in the structure of the appendages or of the mouth parts.

In 1912 the second molt for a rearing of 213 females that emerged July 22 extended over a period of 10 days. The maximum daily molt was upon the thirty-eighth day after emergence, and 50 per cent had molted by the fortieth day. A rearing of 100 females that emerged upon August 9, 1912, made its maximum molt upon the thirty-eighth day after emergence. One-half of the rearing molted upon that day.

In the orchards at Mont Alto, Pa., in 1912, the maximum molt was upon the fortieth day. In all the rearings there was a very short interval between the first molt and the maximum daily molt. This interval varied from 2 to 5 days, with 3 days as the normal time.

In 1913 observations were made upon two rearings, one of which emerged June 24. This rearing of 174 females made its maximum daily molt upon the thirty-ninth day. Reference to Table XXII will show that the first molt for this rearing was made upon the twenty-second day. It was slightly delayed by a storm, but the larvæ reached the maximum of the second molt on the thirty-ninth day; that is, 1 day ahead of the average time for the orchard larvæ.

TABLE XXIII.—*Age of the terrapin scale at the second molt as determined from the maximum daily molt.*

Year.	Material.	Number of specimens.	Age at the maximum daily molt.	Weather conditions.
			<i>Days.</i>	
1912....	Brood of July 22.....	213	38	Unfavorable. Do. Do.
	Brood of Aug. 9.....	100	38	
	Brood of orchard ¹	1,765	37	
	Average for the year.....		37.1	
1913....	Brood of June 24.....	174	39	Favorable. Do. Do.
	Brood of June 26.....	69	37	
	Brood of orchard ¹	190	36	
	Average for the year.....		37.3	

¹ These data refer to larvæ reared upon isolated twigs at Mont Alto, Pa., and not to the entire orchard brood.

The foregoing data show that the averages for the two years differ by only two-tenths of a day. Some of the individuals, however, departed 4 or 5 days from this average, while in 1912 some specimens made the molt as late as the forty-second day and in 1913 some made it as early as the thirty-second day.

LEAF PHASE OF THE THIRD INSTAR.

After molting to the third instar the females remain motionless on the underside of the leaf for a period of 1 day while they secrete a very thin dorsal scale which protects them during migration to the twigs.

The individuals vary in size in the same season, and there is a slight variation in the average size from year to year. The measurements from 11 specimens showed a minimum length of 1.387 mm. and a minimum width of 0.862 mm.; a maximum length of 1.65 mm. and a maximum width of 1.074 mm.; an average length of 1.545 mm. and an average width of 0.995 mm. The average length in 1912 was 1.465 mm. and the average width 0.974 mm. In 1913 the average length was 1.64 mm. and the average width 1.02 mm., showing an increase in size for the latter year of 0.175 mm. in length and 0.046 mm. in width.

MIGRATION TO THE TWIGS.

The twigward migration of the females starts about the 1st of August and reaches its maximum before the middle of the month, after which it continues in a small way until the leaves fall. In the vicinity of Mont Alto, Pa., from 80 to 90 per cent migrate between August 8 and August 20. (Pl. I, fig. 4.)

Table XXIV gives data from observations made upon 1,494 migrating females during 1912 at Mont Alto, Pa. The observations in Part I were made upon larvæ that settled naturally upon orchard trees. The material considered was isolated with tree tanglefoot August 1 and the females as they migrated were removed and counted at two-day intervals. The age at which these particular larvæ migrated is not definitely known, but was about 40 days. The rearing of July 22 (Part II) migrated from the thirty-ninth to the fiftieth day after emergence, and made its maximum daily migration August 30, which was the thirty-ninth day. The rearing of August 9 (Part III) migrated from the thirty-first to the fifty-seventh days and made its maximum daily migration upon September 15, which was the thirty-seventh day. It is evident from a comparison with figure 11 that the maximum in Part III was retarded. A cold wave, which started September 7, retarded the maximum daily migration, causing it to be nearly a week after the start.

TABLE XXIV.—*The time of the twigward migration of 1,483 female larvæ of the terrapin scale, Mont Alto, Pa., 1912.*

Part.	Material observed.	Number of larvæ.	Twigward migration.		Part.	Material observed.	Number of larvæ.	Twigward migration.	
			Date.	Number migrated.				Date.	Number migrated.
I....	Orchard larvæ, Mont Alto, Pa.	976	Aug. 12	0	III...	Rearing of August 9.	294	Sept. 8	0
			14	283				9	2
			16	176				10	5
			18	202				11	13
			20	120				12	24
			22	65				13	23
			24	33				14	18
			26	32				15	65
			28	24				16	20
			30	13				17	18
			Sept. 1	10				18	20
			3	12				19	11
			5	6				20	24
II....	Rearing of July 22.	213	Aug. 30	61				21	5
			31	19				22	10
			Sept. 1	6				23	5
			2	50				24	8
			3	20				25	9
			4	17				26	3
			5	14				27	3
			6	10				28	1
			7	7				29	0
			8	4				30	0
			9	3				Oct. 1	1
			10	2				2	0
			11	0				3	0
			12	0				4	0
								5	6
Total.....							1,483		

The orchard larvæ considered in Table XXIV, Part I, had very favorable weather during their twigward migration. The relation of this migration to the prevailing temperature is shown graphically in figure 9. The migration curve shows the shortness of the interval between the start of migration and its maximum.

The migration started on August 13 and was 50 per cent complete upon August 17. Thus, one-half of the migration was made during

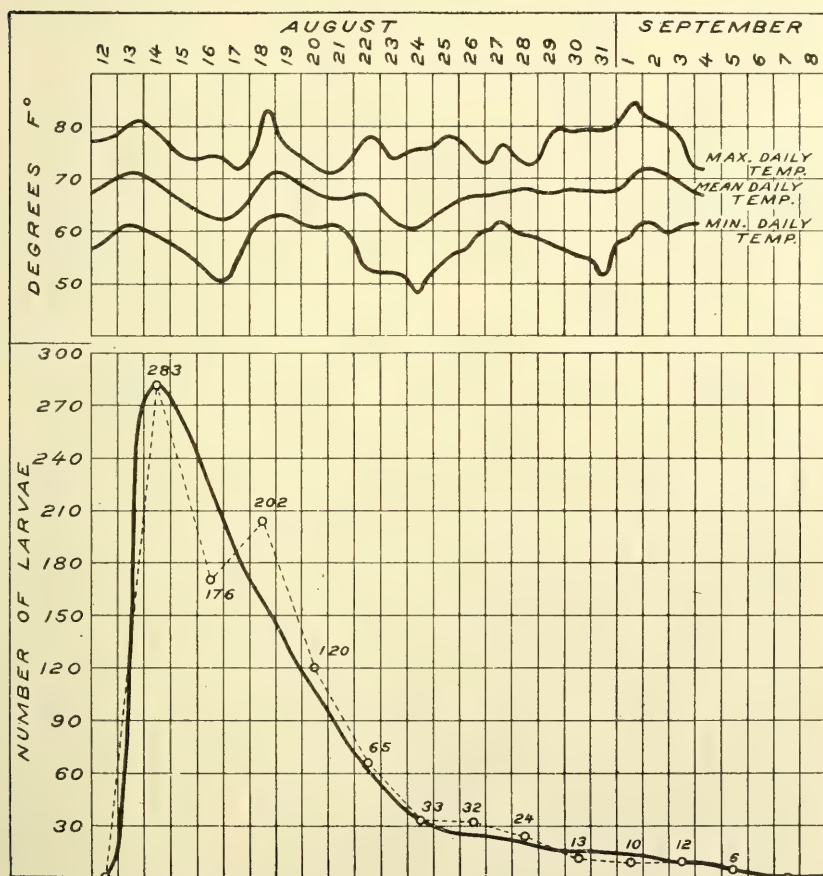


FIG. 9.—Curve of the twigward migration of the terrapin scale for the orchard larvæ of 1912. (Original.)

the first four days of the period. This curve is typical for the migration in favorable seasons.

The larvæ considered in Table XXIV, Part II, encountered very unfavorable weather during the period of migration. Cold interfered at the beginning, and rain continued throughout most of the period. The effects of these conditions are shown graphically in figure 10. The solid curve represents a normal migration, the dotted curve the migration under prevailing conditions. This graph

also includes the data for rainy and clear days. August 28 was clear and favorable and the following day was rainy. August 30 was clear, and migration started. August 31 to September 2 was

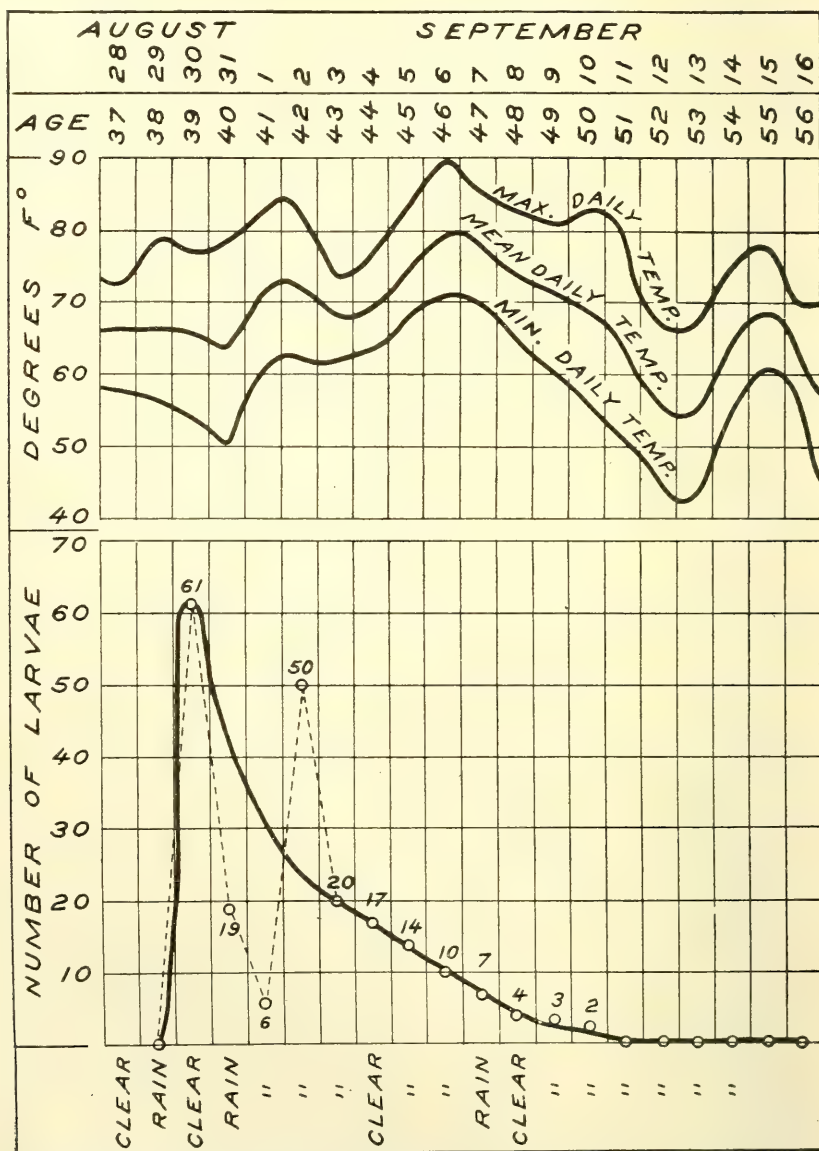


FIG. 10.—Curve of the twigward migration of the terrapin scale for a rearing that emerged July 22, 1912. (Original.)

rainy, but on the last of these days it was clear and hot in the afternoon, thus permitting a heavy migration. The remainder of the period was clear, except for slight rains upon September 3 and 7.

During the migration of the rearing of July 22 the maximum daily temperature rose gradually from 73° F. on August 28 to 85° F. upon September 1, after which it fell to 74° F. upon September 3, and then rose abruptly to 90° F. upon September 6. It then dropped to 67° F. upon September 12. The average daily temperature remained nearly constant at 66° F. from August 28 to August 31,

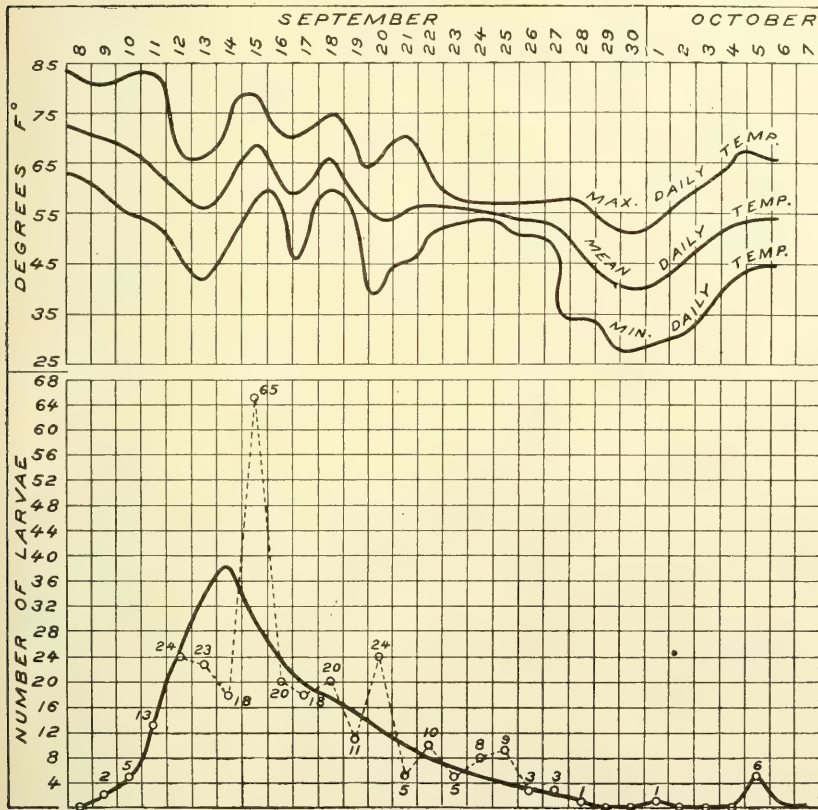


FIG. 11.—Curve of the twigward migration of the terrapin scale for a rearing that emerged August 9, 1912. (Original.)

when it rose abruptly to 73° F. upon September 1. During September 2 and 3 it made a gradual drop to 68° F., and then rose in a gradual way to 80° F. upon September 6. This was followed by a gradual drop to 54° F. upon September 12. This rearing gave its maximum daily migration when 39 days old and its 50 per cent of migration four days later.

The larvæ considered in Part III of Table XXIV were a late rearing. They had favorable weather to near the end of the second instar, but very unfavorable weather during the twigward migration. The

relation of the temperature to the migration of this rearing is shown in figure 11.

This migration extended from September 8 to October 5, 1912, under unfavorable temperature conditions. There was a drop in the average daily temperature from 71° F. on the first day of migration to 56° F. on the sixth day (September 13). This was followed by a favorable day, when the average temperature rose to 69° F., after which it dropped gradually to 40° F. at the end of September. There was a rainstorm of three days' duration, September 23, 24, and 25, but it came too late to modify the rate of migration to any extent. Under these conditions 95 per cent of the rearing had migrated by the end of the tenth day of migration, or by the fortieth day after emerging. The maximum daily migration was made by this rearing upon the seventh day after the start of migration; that is, upon the thirty-seventh day after emerging. A comparison of the curves, figures 9 to 11, shows that the curve for optimum conditions (fig. 9) tends to have a perpendicular ascending slope and a very steep receding slope, and that unfavorable conditions tend to flatten the curve and to cause serrations in the slopes.

TIME REQUIRED FOR MIGRATION.

The migration is made during the hottest part of the day. Usually very few migrating specimens can be taken until after 12.30 p. m., because of the low morning temperatures. The larvæ start upon this migration when the temperature reaches 70° F. By 1.30 p. m. larvæ are usually moving in great numbers upon the twigs. By 3 p. m. nearly all migrants have selected their locations and permanently established themselves.

LONGEVITY OF MIGRANTS.

In case the twigward migrants are prevented from attaching, they can live for 2 days, and a small percentage even for 3 days before dying.

The following experiment was made to determine the longevity of a twigward migrant when prevented from attaching. A quantity of material was kept under observation from August 30, 1913, until one of the larvæ was observed to start upon its migration. This specimen was then placed upon wrapping paper for observation. The details of these observations are shown in Table XXV.

TABLE XXV.—Rate per hour and distance traveled by a migrating larva of the terrapin scale upon wrapping paper during the total time of the twigward migration, Mont Alto, Pa., 1912.

LARVA NO. 1.

Observed—		Interval.	Distance.	Rate per hour.	Temperature.
		Min.	Cm.	Cm.	° F.
Aug. 30	2.45 p. m.				70
	3.15 p. m.	30	30.6	61.2	84
	3.30 p. m.	15	27.8	111.2	88
	4 p. m.	30	62	124	90
	4.30 p. m.	30	61.5	123	80
	4.45 p. m.	15	16.2	64.8	78
	5 p. m.	15	15.4	61.6	77
	5.15 p. m.	15	9.1	36.4	76
	6 p. m.	45	9.3	12.4	72
Total.....		3 h. 15 m.	231.9		
Aug. 31	2.30 p. m.				70
	3.15 p. m.	45	8	10.6	86
	3.30 p. m.	15	1.7	6.8	88
	4.15 p. m.	45	17.3	23.06	82
	4.30 p. m.	15	3.2	12.8	78
	6 p. m.	90	8.6	5.7	75
	6.30 p. m.	30	2.7	5.4	72
Total.....		4 h.	41.5		
Sept. 1	8.45 a. m.				70
	9.20 a. m.	35	3.6	6.17	72
	9.30 a. m.	10	.4	2.4	80
	10 a. m.	30	7.9	15.8	86
	11 a. m.	60	25.1	25.1	88
	12 noon	60	12.1	12.1	84
Total.....		3 h. 15 m.	49.1		

Migration, first day: Migration started at 2.45 p. m., and continued until 6 p. m., when it stopped. The larva remained motionless all night. During the time of migration, which was 3½ hours, the larva traveled 231.9 cm. It traveled at a rate of 124 cm. per hour from 3.30 p. m. to 4 p. m., with a rate of 123 cm. per hour from 4 to 4.30 p. m. The rate then fell off rapidly after 4.30, being 36.4 cm. per hour for the interval from 5 to 5.15 p. m., and only 12.4 cm. per hour for the interval from 5.15 p. m. to 6 p. m. The temperature during this migration rose gradually from 70° F. at 2.45 p. m. to 90° F. at 4 p. m., and then fell to 72° F. at 6 p. m. The highest rate of travel therefore coincided closely with the time of highest temperature.

Migration, second day: The larva remained motionless from 6 p. m., August 30, until 2.30 p. m., August 31, when it again started to migrate and continued until 6.30 p. m., an interval of 4 hours, during which it showed signs of exhaustion and traveled only 41.5 cm. The rate per hour gradually increased from the start until it reached a maximum of 23.06 cm. per hour for the period 3.30 p. m. to 4.15 p. m., after which it dropped to 12.8 cm. per hour during the next interval and then to 5.4 cm. per hour for the last interval. The temperature during this second day's migration was slightly lower than on the previous day. The temperature at the resumption of migration, 2.30 p. m., was 70° F., from which it rose rapidly to a maximum of 88° F. at 3.30 p. m., and then dropped gradually to 72° F. at 6.30 p. m.

Migration, third day: The third day was very warm. The larva had remained motionless from 6.30 p. m., August 31, to 8.45 a. m. of the following day, at which time it resumed migration and continued until 12 noon, when it died, after traveling for 3½ hours, during which time it advanced 49.1 cm. The rate of travel, which was very low, reached its maximum of 25.1 cm. per hour in the interval ending at 11 a. m., after which it dropped to 12.1 cm. per hour for the interval between 11 a. m. and 12 noon. The temperature during the third day was very favorable. It reached 70° F.

at 8.45 a. m., at which time the larva resumed its migration. At 9.30 a. m. the temperature was 80° F., at 10 a. m. 86° F., and at 11 a. m. 88° F., from which hour it dropped to 84° F. at noon, when the experiment was terminated by the death of the larva.

Ordinarily larvæ start migrating when the temperature reaches 70° F., and the rate of travel increases in nearly the same ratio as the increase in temperature above 70° F. Larvæ, if unattached, become motionless when the temperature falls below 72° F. The female

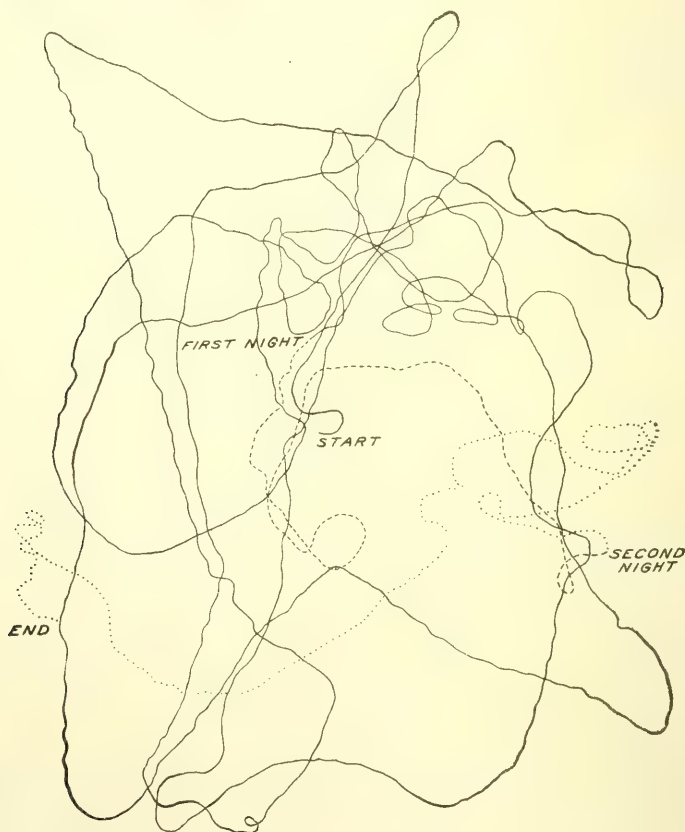


FIG. 12.—Tracing of the total twigward migration of a female larva of the terrapin scale. Reduced 8 times. Total distance traveled, 322.5 cm. (Original.)

under observation started migration August 30 at 2.40 p. m., and died September 1 at 12 noon, having lived 2 hours and 40 minutes less than 3 days, and having traveled over smooth paper a distance of 322.5 cm. (10½ feet). (Fig. 12.) This was undoubtedly farther than the average specimen is able to travel upon its host plant. *There is therefore very little chance of the larvæ crawling to adjacent trees unless the limbs are in contact.*

A second female larva (Table XXV), captured August 26, during the first day of migration, was placed upon wrapping paper at 2.25

p. m. This larva traveled 192 cm. in 2 hours and 35 minutes at an average rate per hour of 74.84 cm. (Fig. 13.)



FIG. 13.—Tracing of a female larva of the terrapin scale for 2 hours and 35 minutes during the first day of the twigward migration. Distance traveled, 192 cm. (Original.)

TABLE XXVI.—Rate per hour and distance traveled by two migrating larvæ of the terrapin scale on wrapping paper.

Larva number.	Observed—	Interval.	Distance.	Rate per hour.
		<i>Min.</i>	<i>Cm.</i>	<i>Cm.</i>
2.....	2.25 p. m.	22	58	158.88
	2.47 p. m.	53	57	64.23
	3.40 p. m.	20	31.6	94.8
	4 p. m.	25.7	25.7	34.26
	4.45 p. m.	15	21	84.00
	5 p. m.			
Total.....		2 hrs. 35 m.	192	74.84
3.....	11 a. m.			
	11.30 a. m.	30	53.5	101.5
	12 noon...	30	45	90.
	12.30 p. m.	30	48.1	96.2
	1 p. m.	30	37.5	75
Total.....		2 hrs.	184.1	92.05

A third larva, Table XXVI, taken September 1, 1912, at 11 a. m., while in the first day of migration, gave a maximum rate per hour of 101 cm., at 88° F., and an average rate for 2 hours of 92.05 cm. (Fig. 14.)

The rate of migration depends both upon the temperature above 70° F. and upon the length of time that has elapsed since the migration started.

It is very exceptional for specimens to require more than one day for the twigward migration. More than 90 per cent of the females

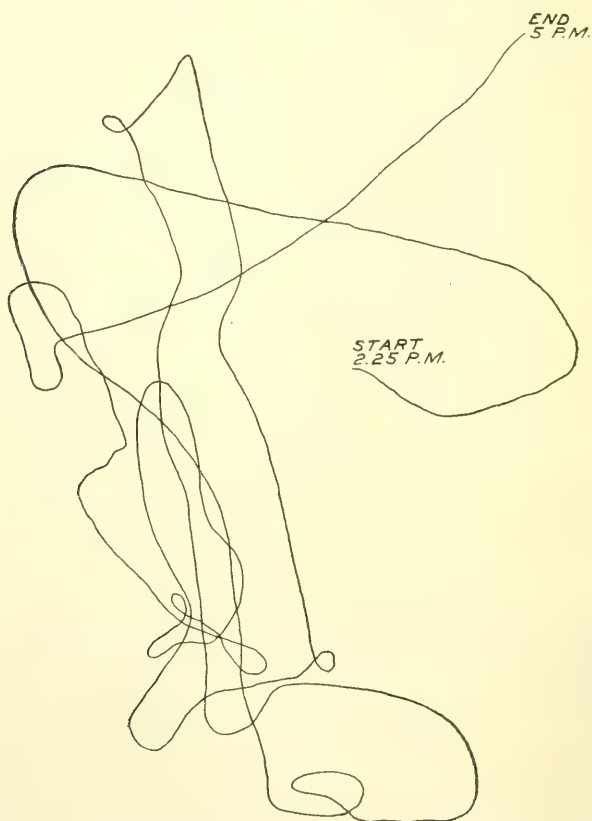


FIG. 14.—Tracing of a female larva of the terrapin scale for the first two hours of the twigward migration. Reduced 8 times. Total distance, 184.1 cm. (Original.)

complete this migration during the first 4 hours. Females may occasionally shift to a more favorable position during the second and third days' sojourn upon the twigs, but after this they remain in one place.

During the day preceding the twigward migration the female larvæ secrete a thin scale which covers the dorsal surface and gives rigidity to the flat, leaf-shaped body. The larvæ in migrating pass down the petiole and move along the twigs toward the region of greatest illu-

mination. They finally reach the tips of the twigs, where they locate by preference upon the basal part of the young growth. Many, however, locate upon 1-year-old wood, and a few upon the 2-year-old wood. Other parts of the tree are very seldom infested. The larvæ settle by preference upon the underside of horizontal limbs and upon the unshaded side of vertical branches. There is a tendency for them to group themselves in rows upon the illuminated sides of the twigs. The individual scales within these rows are not necessarily in alignment, either with their neighbors or with the axis of the twig. This linear arrangement results solely from their instinctive desire to locate in the area of greatest illumination, which, from the nature of the twigs upon which they locate, is always many times longer than wide. During migration the mortality is very low.

The females are very flat and have the pale yellow color of the preceding stages. This color appears rather lighter than in the second instar, due, no doubt, to the effect of the nearly transparent dorsal scale. The only colored portions at this time are the brown eye-spots and the chitinized anal plates.

Specimens measured in 1912 and in 1913 were from 1.23 to 1.57 mm. in length and from 0.65 to 1.12 mm. in width, the average height being about 0.1 mm. The average size for both seasons was, length 1.47 mm., width 0.98 mm.

THE FEMALE UPON THE TWIG: DEVELOPMENT DURING THE FIRST 20 DAYS.

After attaching to the twigs the young females begin a period of rapid growth. A small red blotch, which appears over the oral region either during the migration or immediately after it, begins at once to enlarge and to form itself into a narrow band of a reddish-brown color which extends backward along the middorsal line until by the sixth day it reaches the anal plates. (Fig. 15, *a*.) Meanwhile the dorsum changes from a flat to a mildly arched surface and the larva increases from about 1.54 to 1.65 mm. in length and in width from 1.03 to 1.29 mm. When the dorsal band reaches the anal plates it forks. Each fork when developed equals the original band in width and is slightly longer than wide. These forks start about the sixth day and are about one-half completed by the eighth day. From the sixth to the tenth day there is a very decided arching of the dorsum. Growth is greatest just in front of the anal plates, and the elongation of the dorsum at this place first constricts and then breaks the dorsal band, leaving a short piece of it attached to the forked portion that is forming about the anal plates. (Fig. 15, *b*.) Later the anterior piece is displaced forward and shrinks until it becomes inconspicuous just above the oral region. About the eleventh day after migrating, the forks of the dorsal band are completed. This band is a secondary sexual character, which, after copulation, fades and blends with the

reddish-brown ground color. The rent between the two parts remains unpigmented and shows in mature specimens as the characteristic dorsal stripe. (Pl. I, fig. 5, *b*, p. 8, and text fig. 15, *d*.)

Up to and including the eighth day the general aspect is strictly larval, except for the slight arching of the dorsum and for the dorsal

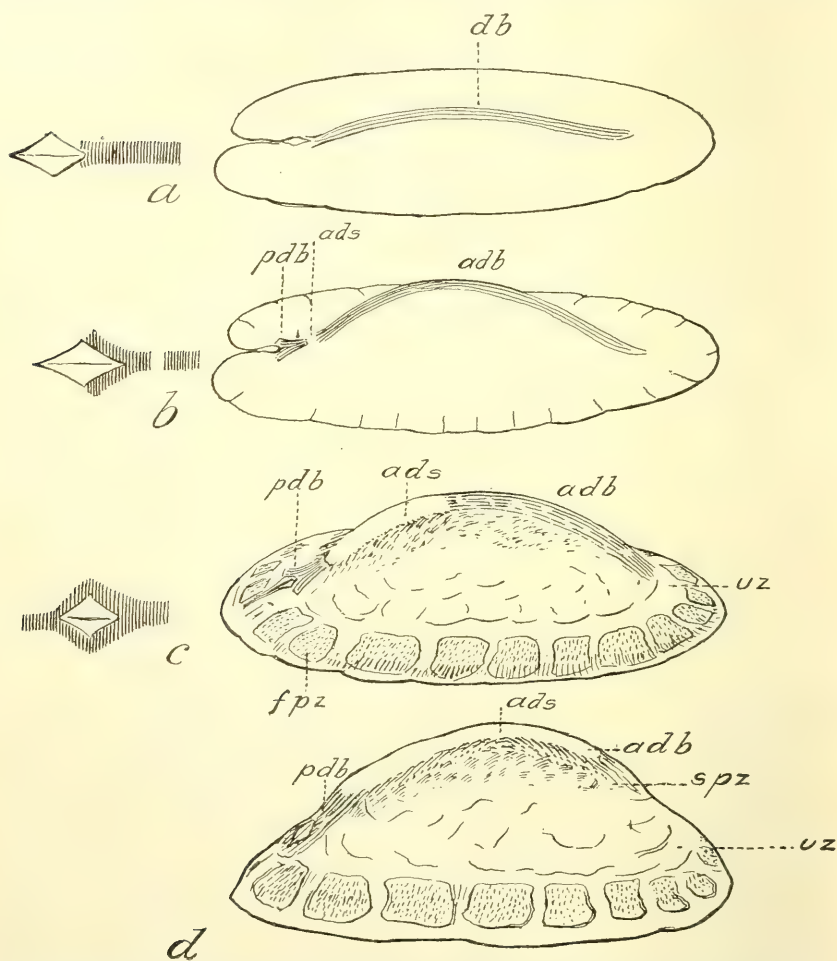


FIG. 15.—Diagrammatic representation of the color and markings of the female terrapin scale: *a*, Larva, seventh day upon the twig; *b*, larva, eleventh day upon the twig; *c*, larva, fifteenth day upon the twig; *d*, larva, twentieth day upon the twig and after; *db*, dorsal band; *adb*, anterior segment of dorsal band; *pdb*, posterior segment of dorsal band; *fpz*, first pigment zone; *spz*, second pigment zone; *ads*, adult dorsal stripe; *uz*, unpigmented zone. (Original.)

band. At the ninth day the female is about equally adult and larval in appearance. At this time the pale yellow body color of the larva begins to turn to a reddish amber and the characteristic crimps at the margin of the derm (fig. 15, *b*) begin to appear. In the depressions formed by the crimping, a brownish pigment develops and marks

them in sharp contrast with the narrow ridges of the crimps. These pigmented depressions blending form the first pigment zone or marginal pigmentation. (Fig. 15, *fpz*.) By the fourteenth day the female has become decidedly adult, both in shape and color. The first pigment zone now reaches completely around the dorsum and extends upward as far as the anal plates; the dorsal band has blended with the reddish-brown ground color, and a second zone of pigmentation has formed about the rent in the original dorsal band, thus transforming it into the permanent reddish-brown stripe which is so characteristic of the mature female. (Fig. 15, *ads*.) The second zone of pigment is composed of dark-brown granules similar to those in the marginal region. It surrounds the amber-colored gap in the original dorsal band and extends downward and outward nearly to the marginal zone, from which it is separated by an irregular unpigmented zone (fig. 15, *uz*) which lies parallel to the edge of the dorsum at about the height of the anal plates. By the twentieth day the female has assumed both the characteristic shape and color of the adult, but the general color is not so bright as in the case of older specimens. After the twentieth day there is no change in the color pattern. The pigmentation, however, deepens and the insect continues to grow, but at a decreasing rate, until it hibernates.

The data in Table XXVII show in detail the development of the female up to and including the fifteenth day after attaching to the twig. A very rapid growth is also shown during this period. The ground color changes from light yellow to reddish brown; the dorsal band develops and breaks and the adult pigmentation starts.

To obtain more extended observations upon the twig-attached females, 100 larvæ were taken August 15, 1913, while making the twigward migration, and placed upon a vigorous potted peach tree. This tree was kept under orchard conditions and such of the specimens as had accessible locations were numbered and observed from time to time through a Zeiss binocular. These observations were continued to the sixty-seventh day after migrating. Data from these specimens are given in Table XXVIII; they supplement Table XXVII.

TABLE XXVII.—Details of the growth of the female terrapin scale during the first 15 days upon the twig, *Mont Alto, Pa., 1913.*

No.	Original symbol.	Emerged.	Observed.	Age.	Period on twig.	Length.	Width.	General body color.	Dorsal band.	Anal Y.	Edge crimped.	Adult pigmentation.
1	A 1"	June 24	Aug. 7	44	Days.	Mm.	Mm.	Light yellow	Just starting.	None	Not	None
2	A 2"	do.	do.	44	1	1.625	1.1	do.	do.	do.	do.	Do.
3	A 3"	do.	do.	44	1	1.65	1.1	do.	do.	do.	do.	Do.
4	B 10"	do.	Aug. 6	45	2	1.525	1.1	do.	do.	do.	do.	Do.
5	B 11"	do.	Aug. 8	45	2	1.75	1.2	do.	Half completed.	do.	do.	Do.
6	B 12"	do.	do.	45	2	1.675	1.075	do.	do.	do.	do.	Do.
7	B 12"	do.	do.	45	2	1.525	1.15	do.	do.	do.	do.	Do.
8	A 1"	do.	Aug. 11	48	2	1.35	1.15	do.	One-fourth.	do.	do.	Do.
9	A 1"	do.	Aug. 10	47	4	1.75	1.15	do.	Nearly complete.	do.	do.	Do.
10	A 2"	do.	Aug. 13	50	4	1.475	1.95	do.	Complete.	do.	do.	Do.
11	B 4	do.	Aug. 10	47	4	1.75	1.1	do.	do.	do.	do.	Do.
12	B	do.	Aug. 11	48	5	1.375	1.025	do.	do.	do.	do.	Do.
13	A 2"	do.	Aug. 13	50	7	1.775	1.125	do.	One-fourth.	do.	do.	Do.
14	C 4	do.	do.	50	7	1.375	1.125	do.	Complete.	do.	do.	Do.
15	C	do.	do.	51	8	1.65	1.05	do.	do.	Forming.	do.	Do.
16	D	do.	Aug. 14	51	8	1.35	1.00	do.	do.	do.	do.	Do.
17		do.	do.	51	8	1.85	1.275	do.	do.	do.	do.	Do.
18	2	do.	Aug. 11	48	8	2.00	1.5	do.	do.	do.	do.	Do.
19	3	do.	do.	48	8	1.85	1.3	do.	do.	do.	do.	Do.
20	3	do.	Aug. 13	50	10	1.9	1.425	Reddish yellow.	do.	Formed.	do.	First zone forming.
21	A	do.	do.	50	10	1.9	1.425	do.	do.	do.	do.	Do.
22	B	do.	Aug. 14	51	11	1.875	1.475	Reddish brown.	Broken.	do.	Crimped.	First zone advanced.
23	C	do.	do.	51	11	1.95	1.55	do.	do.	do.	Slightly	Do.
24	C	do.	do.	51	12	1.8	1.225	do.	do.	do.	do.	Do.
25	E	do.	Aug. 18	55	12	1.8	1.195	do.	do.	do.	do.	First zone forming.
26	B	do.	do.	55	15	2.00	1.45	do.	do.	do.	Crimped.	First zone advanced.
		do.	do.	55	15		1.55	do.	do.	do.	do.	First zone advanced.

TABLE XXVIII.—Growth and color changes of female terrapin scales from the fourth to the sixty-seventh day after the twigward migration, *Mont Alto, Pa.*, 1913.

Observation No.	Number of specimens observed.	Date observed.	Period on twig.	Length.	Width.	Height.	General body color.	Degree of completion of the dorsal band.	Condition of the dorsal band.	Degree of completion of the anal band.	Condition of edge.	Amount of pigmentation as in adult.
1.	1	Aug. 19	<i>Days.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>	Light yellow	Three-fourths.	Unbroken.	Incomplete.	Uncrimped.	None.
2.	2	do.	4	1.525	1.125	do.	do.	Nearly	do.	do.	do.	Do.
3.	3	do.	4	1.575	1.025	do.	do.	do.	do.	do.	do.	Do.
4.	4	do.	4	1.525	1.05	do.	Turning amber.	Three-fourths.	do.	do.	Slight crimp.	Do.
5.	7	do.	4	1.7	1.15	do.	Light yellow	Nearly	do.	do.	Uncrimped.	Do.
6.	8	do.	4	1.7	1.15	do.	do.	Incomplete.	do.	do.	do.	Do.
7.	10	do.	4	1.72	1.15	do.	do.	Complete.	do.	do.	do.	Do.
8.	9	do.	4	1.75	1.075	do.	do.	Incomplete.	do.	do.	do.	Do.
9.	11	do.	4	1.6	1.15	do.	do.	Nearly	do.	do.	do.	Do.
10.	12	do.	4	1.6	1.05	do.	do.	do.	do.	do.	do.	Do.
11.	13	Aug. 20	5	1.575	1.2	do.	do.	Complete.	do.	do.	do.	Do.
12.	14	do.	5	1.6	1.1	do.	do.	do.	do.	do.	do.	Do.
13.	15	do.	5	1.625	1.075	do.	Light amber	do.	do.	do.	Slight crimp.	Do.
14.	16	do.	5	1.625	1.075	do.	Light yellow	do.	Breaking.	do.	do.	Do.
15.	17	do.	5	1.575	1.00	do.	do.	do.	Unbroken.	do.	Slight crimp.	Do.
16.	8	do.	5	1.75	1.00	do.	do.	do.	Breaking.	do.	do.	Do.
17.	20	do.	5	1.6	.95	do.	do.	do.	do.	do.	do.	Do.
18.	18	do.	5	1.625	1.50	do.	do.	do.	do.	do.	do.	Do.
19.	21	do.	5	1.6	1.025	do.	do.	Incomplete.	Unbroken.	do.	Uncrimped.	Do.
20.	22	do.	5	1.5	.925	do.	do.	Complete.	do.	do.	do.	Do.
21.	1	Aug. 23	8	1.55	1.1	do.	Amber color.	Three-fourths.	Broken.	do.	do.	Do.
22.	2	do.	8	1.70	1.075	do.	Light color.	do.	do.	Partly complete.	Slight crimp.	Do.
23.	3	do.	8	1.525	1.05	do.	Light color.	do.	Breaking.	One-half complete.	do.	Do.
24.	4	do.	8	1.725	1.275	do.	Reddish amber	do.	Broken.	One-fourth complete.	do.	Do.
		do.	8	1.9	1.325	do.	do.	do.	do.	do.	do.	Do.
25.	8	do.	8	1.75	1.275	do.	Light amber	do.	do.	Nearly complete.	do.	Do.
26.	9	do.	8	1.7	1.175	do.	Light yellow	do.	do.	Complete.	Uncrimped.	Do.
27.	11	do.	8	1.625	1.225	do.	do.	do.	Breaking.	Incomplete.	do.	Do.
28.	12	do.	8	1.65	1.15	do.	Reddish amber	do.	Broken.	Complete.	Slight crimp.	Trace.
29.	13	do.	8	1.625	1.255	do.	do.	do.	do.	do.	do.	Do.
30.	14	do.	8	1.75	1.125	do.	do.	do.	do.	do.	do.	Do.
31.	15	do.	8	1.75	1.150	do.	do.	do.	do.	do.	Crimped.	One-half first zone.
32.	16	do.	8	1.625	1.125	do.	do.	do.	do.	do.	do.	Do.
33.	1	Aug. 26	11	1.65	1.20	do.	Light yellow	do.	do.	Partly complete.	Uncrimped.	None.
34.	2	do.	11	1.7	1.12	do.	Reddish amber	do.	do.	Complete.	Crimped.	Evident.
35.	7	do.	11	1.725	1.325	do.	do.	do.	do.	do.	do.	Do.
36.	8	do.	11	1.925	1.325	do.	do.	do.	do.	do.	Slight crimp.	None.
37.	14	Aug. 29	14	1.75	1.375	do.	Light amber	do.	do.	do.	Crimped.	First and second zones.
38.	15	do.	14	1.85	1.5	do.	do.	do.	do.	do.	do.	First zone complete.
39.	16	do.	14	1.875	1.5	do.	do.	do.	do.	do.	do.	Do.

TABLE XXVIII.—Growth and color changes of female terrapin scales from the fourth to the sixty-seventh day after the twigward migration, *Mont Alto, Pa., 1913*—Continued.

Observation No.	Number of specimens observed.	Date observed.	Period on twig.	Length.	Width.	Height.	General body color.	Degree of completion of the dorsal band.	Condition of the dorsal band.	Degree of completion of the anal band.	Condition of edge.	Amount of pigmentation as in adult.
			Days.	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>						
40.	17	Aug. 29	14	1.875	1.25		Light amber	Complete	Broken	Complete	Crimped	Slight.
41.	18	do.	14	1.925	1.375		do.	do.	do.	do.	do.	First and second zones.
42.	21	do.	14	1.8	1.2		do.	do.	do.	do.	do.	None.
43.	22	do.	14	1.8	1.25		Reddish amber.	do.	do.	do.	do.	First zone.
44.	23	do.	14	2.05	1.375		do.	do.	do.	do.	do.	Do.
45.	2	1 Sept. 3	19	2.00	1.5		do.	do.	do.	do.	do.	Do.
46.	3	do.	19	1.96	1.49		do.	do.	do.	do.	do.	First and second zones.
47.	4	do.	19	1.913	1.588		do.	do.	do.	do.	do.	Do.
48.	7	do.	19	1.96	2.05		do.	do.	do.	do.	do.	Do.
49.	4	do.	19	2.146	1.806		do.	do.	do.	do.	do.	Do.
50.	9	do.	19	2.05	1.68		do.	do.	do.	do.	do.	Do.
51.	11	do.	19	1.866	1.68		do.	do.	do.	do.	do.	Do.
52.	12	do.	19	2.05	1.726		do.	do.	do.	do.	do.	Do.
53.	14	do.	19	2.24	1.68		do.	do.	do.	do.	do.	Do.
54.	15	do.	19	1.96	1.493		do.	do.	do.	do.	do.	Do.
55.	16	do.	19	2.053	1.54		do.	do.	do.	do.	do.	Do.
56.	17	do.	19	2.006	1.493		do.	do.	do.	do.	do.	Do.
57.	18	do.	19	2.05	1.49		do.	do.	do.	do.	do.	Do.
58.	21	do.	19	1.963	1.4		do.	do.	do.	do.	do.	Do.
59.	22	do.	19	1.773	1.31		do.	do.	do.	do.	do.	Do.
60.	23	do.	19	1.96	1.493	0.615	do.	do.	do.	do.	do.	Do.
61.	1	Oct. 21	67	2.035	1.677		do.	do.	do.	do.	do.	Complete.
62.	2	do.	67	2.035	1.76	.66	do.	do.	do.	do.	do.	Do.
63.	3	do.	67	2.035	1.76	.66	do.	do.	do.	do.	do.	Do.
64.	4	do.	67	2.255	1.97	.66	do.	do.	do.	do.	do.	Do.
65.	7	do.	67	2.2	2.15	.66	do.	do.	do.	do.	do.	Do.
66.	11	do.	67	1.98	1.705	.55	do.	do.	do.	do.	do.	Do.
67.	12	do.	67	2.09	1.87	.715	do.	do.	do.	do.	do.	Do.
68.	15	do.	67	2.145	1.65	.715	do.	do.	do.	do.	do.	Do.
69.	16	do.	67	2.145	1.651	.517	do.	do.	do.	do.	do.	Do.
70.	18	do.	67	2.09	1.705	.66	do.	do.	do.	do.	do.	Do.
71.	21	do.	67	2.145	1.995	.495	do.	do.	do.	do.	do.	Do.
72.	22	do.	67	1.925	1.54		do.	do.	do.	do.	do.	Do.
73.	23	do.	67	2.145	1.65	.66	do.	do.	do.	do.	do.	Do.

THE FEMALE UPON THE TWIG: RATE OF GROWTH.

To determine the relative rate of growth of females after attaching to the twigs Table XXIX was compiled from the data obtained in 1913. This shows an increase from attachment on the twigs to the sixty-seventh day of 500 per cent in height and a pronounced increase in length and width. It is evident from this table that nearly all the growth takes place during the first 19 days.

TABLE XXIX.—*Size of twig-attached females of the terrapin scale after the specified days upon the twigs, Mont Alto, Pa., 1913.*

Date.	Number of specimens.	Period on twig.	Average length.	Average width.	Average height.
		<i>Days.</i>	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>
Aug. 1...	10	(¹)	1.542	1.03	0.125
Aug. 7...	3	1	1.600	1.058	.....
Aug. 8...	3	2	1.65	1.141	.....
Aug. 19...	10	4	1.649	1.297	.208
Aug. 20...	10	5	1.619	1.226	.....
Aug. 23...	13	8	1.686	1.177	.....
Aug. 26...	4	11	1.762	1.25	.....
Aug. 29...	8	14	1.887	1.331	.....
Sept. 3...	13	19	1.996	1.592	.615
Oct. 21...	16	67	2.057	1.680	.625

¹ Just attached.

THE FEMALE UPON THE TWIG: MOVEMENT AFTER ATTACHING TO THE TWIGS.

It is very doubtful whether the females ever reattach after the first week's sojourn upon the twigs. During the first few days specimens have been observed to move, but whether or not the proboscis had been inserted into the host is unknown. Efforts were made to determine this, but no data were obtained. However, observations made upon specimens attached to slowly drying twigs indicate that they do not change position after the eleventh day.

THE DERM.

With the arching of the dorsum during the first week the flat wax scale which protected the female larva during the migration from leaf to twig scales off; meanwhile the exposed surface thickens and hardens until by the end of the week it is so rigid that it responds to the growth changes by crimping. This hardening and thickening of the dorsum which produces the hard shell-like derm is completed by the twenty-fifth day. The excretion of wax, however, continues and wax flakes can be found attached to the derm up to the time of death.

HONEYDEW.

The attachment of the females to the twigs marks the beginning of the maximum period of honeydew deposit. If it were not for the deposit at this time the honeydew would be of very little economic

importance. This period of excretion extends to the time of hibernation, but practically all the honeydew is deposited during the first 25 days.

The anal apparatus is specially adapted to the excretion of honeydew. The anal plates, which are situated near the posterior end of the derm, are so hinged at their anterior ends that they can be both elevated and separated. When in this position they expose the anal chamber which lies just below them. This chamber is bounded laterally by the body lobes and connects ventrally with the brood chamber, while a cloacal cavity extends forward, within which there is a retractile spindle-shaped rectum, at the distal extremity of which the anal aperture is located. It is surrounded by a fringe of eight filaments called the anal ring. During repose the rectum occupies the anterior part of the cloacal cavity, and the anal fringe, which is folded into a cylindrical mass, occupies the posterior part. When the scale is not excreting the anal cavity is empty and closed at the top by the lidlike anal plates. Preparatory to excretion the anal plates are elevated and separated; the rectum with its fringe is drawn backward from the cloacal cavity into the anal chamber, from which it is thrust through the opening between the elevated anal plates. Contraction of the muscular walls of the rectum causes the contents to ooze into the basket formed by the filaments of the anal ring, where it forms a bubble which is held in place upon the end of the rectum by the supporting filaments, much as a jewel is held in its setting. When the bubble is fully formed it bursts, hurling the liquid composing it in the form of minute drops to a distance of from 3 to 8 inches. Cohesion between the honeydew and the filaments of the fringe is very slight. As a result no honeydew remains upon the fringe after the bursting of the bubble. The rectum is always withdrawn and the anal cavity closed after each expulsion. The deposit of honeydew from the twig-attached females becomes noticeable in orchards during the first week in August and rapidly increases in amount during the remainder of the month. At Midvale, Pa., in 1913, the deposit was first noticed August 4. It was made by the few advanced females then upon the twigs. The amount excreted reached its maximum on August 23, after which the amount upon the trees remained nearly constant until the first week of September. The sooty fungus which develops upon this honeydew increases in abundance with the increased deposit, and by the end of August its black spores have transformed the transparent honeydew into a sooty paste. By the end of the first week in September the leaves, branches, and fruit are covered by a black film of dried honeydew and spores. In some cases the infestation is so severe that the soil under the tree is coated almost as thickly as the limbs. The deposit

appears at its worst upon varieties that ripen after September 1. A basket of sooty peaches, with two normal peaches for comparison, is shown in figure 16.

HIBERNATION.

The scales depend for protection during hibernation upon their protective coloration, their hard derm, and their waxy coating. The color, while conspicuous in detached specimens, blends so nicely with the color of the young twigs as to conceal them effectively. The hard derm protects them from birds and insect enemies, and the wax film protects the insect from rain, surface moisture, and scalecides by preventing their passing under the scale.

SIZE DURING HIBERNATION.

Eulecanium nigrofasciatum passes the winter as an impregnated female. The following measurements, which were taken from fresh specimens at Mont Alto, Pa., February 24, 1913, are typical for the hibernation period: Length, maximum 2.375 mm., minimum 1.80 mm., average 2.072 mm.; width, maximum 2.28 mm., minimum 1.79 mm., average 2.0308 mm.; height, maximum 1.1 mm., minimum 0.725 mm., average 0.9084 mm.

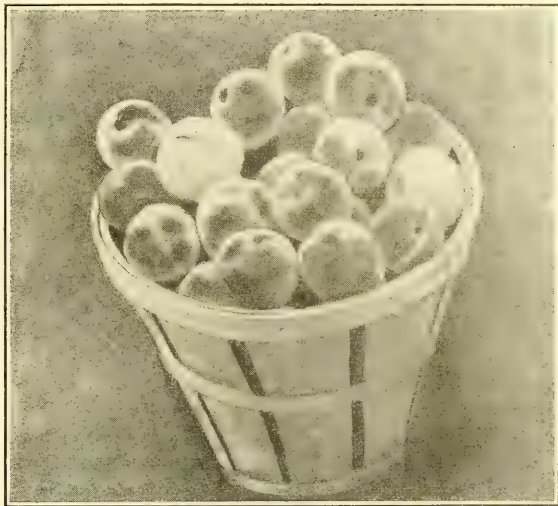


FIG. 16.—A basket of "sooty" peaches with two clean ones for contrast. (Original.)

POSITION ON TWIGS DURING HIBERNATION.

This species when on peach locates exclusively upon the last three seasons' growth, and by far the largest number of specimens is found upon the earliest formed wood of the last growing season. (See Pl. III, figs. 1, 2.)

The females in 1912 continued more or less active until November 12, and they remained dormant until April. This made the hibernating period cover about $4\frac{1}{2}$ months.

MORTALITY DURING HIBERNATION.

Practically every normal female will pass the hibernation period safely unless some accident happens to the host. Specimens at Mont

Alto, Pa., during the winter of 1912-13 passed this period with a mortality of less than 10 per cent. At Midvale, Pa., during the winter of 1913-14, specimens upon poorly nourished trees had a mortality as high as 54 per cent. Neither birds nor other animals make a noticeable attack during hibernation, but there is a strong parasitic attack upon the young females before hibernation. This was especially noticeable during the first week in September.

DEVELOPMENT OF THE MALE.

MALE LARVA, SECOND INSTAR.

In this instar the elongation of the larva and the secretion of the puparium undoubtedly start immediately after the first molt, but it is usually five or six days before they can be detected. The male increases, as is shown in Table XXX, from an average length of 1.03 mm. to an average length of about 1.706 mm., and in width from an average of 0.421 mm. to an average of about 0.830 mm. There is also an appreciable increase in height.

TABLE XXX.—Average measurements of the male terrapin scale in the second instar at various ages between the twenty-fifth and thirty-fourth days, at Mont Alto, Pa.

Year.	Date emerged.	Age.	Number of specimens.	Average length.	Average width.
		<i>Days.</i>		<i>Mm.</i>	<i>Mm.</i>
1912	Aug. 9	25	1	1.031	0.468
1912	...do....	26	2	1.218	.421
1913	June 24	30	14	1.628	.830
1912	Aug. 9	31	4	1.579	.642
1913	June 26	32	13	1.661	.809
1913	June 24	33	13	1.621	.813
1913	...do....	34	8	1.706	.777

In 1912 the instar extended to the fortieth day, but practically all males had shrunk in preparation for the second molt by the thirty-fifth day.

The following table compares the measurements of 54 females in the second instar with 48 males of the same rearing, and shows that the females average 0.168 mm. wider and 0.111 mm. shorter than the males.

TABLE XXXI.—Comparative measurements of male and female larvæ of the terrapin scale during the second instar, Mont Alto, Pa.

Age.	Date emerged.	Number of males.	Length of males.	Width of males.	Number of females.	Length of females.	Width of females.
<i>Days.</i>			<i>Mm.</i>	<i>Mm.</i>		<i>Mm.</i>	<i>Mm.</i>
30	June 24	14	1.628	0.830	7	1.507	0.982
32	June 26	13	1.661	.809	16	1.506	.937
33	June 24	13	1.621	.813	20	1.587	.978
34	...do....	8	1.706	.777	11	1.575	1.012
Total....		48			54		
Average.			1.654	.807		1.543	.975

The male larva stops growth one day before the second molt, after which it shrinks and tends to assume a cylindrical form. The amount of this shrinkage, as is shown, averages 0.16 mm. in length and about 0.137 mm. in width. As a result of this shrinkage the edges of the puparium extend beyond the larva like the eaves of a roof.

TABLE XXXII.—*Shrinkage of 13 male larvæ of the terrapin scale during the last day of the second instar, 1913.*

	July 27.	July 28.	Difference.
	<i>Mm.</i>	<i>Mm.</i>	<i>Mm.</i>
Average length.....	2.17	2.01	0.16
Average width.....	1.075	.9375	.1375

The author's observations indicate that both sexes make the second molt at the same time and that they spend the same number of days in the second instar.

THE PUPARIUM.

The puparium is a transparent protective covering under which the male passes the third, fourth, and part of the fifth instar. It is secreted by dorsal wax pores during the second instar (Pl. II, *a, e*), and has the same dimensions as the full-grown larva, but owing to the shrinking of the larva the puparium at the end of the second instar is the larger. This structure is held in place by elastic bands which extend from points upon its edges to the leaf below. The largest of these is attached directly in front of the head. The ornamentation of the puparium consists of 2 longitudinal lines, 3 cross-lines, and a spear-shaped notch, which coincide in position at the time of its secretion with the anal plates and anal cleft of the larva. The longitudinal lines extend from the anterior end of the anal notch in mildly diverging curves anteriorly to a termination on the lateral edges near the position of the eye-spots of the larva. The cross lines, which are broken, are located at the middle and on the anterior and posterior thirds.

In this species the puparium is always placed upon the underside of the leaf (Pl. III, fig. 3) and never upon the twigs. In this it differs from *Eulecanium corni* Bouché, which frequently has puparia upon the twigs. Twenty-four puparia taken at Mont Alto, Pa., during 1912, had the following sizes: Length, maximum 1.725 mm., minimum 1.443 mm., average 1.641 mm.; width, maximum 0.825 mm., minimum 0.54 mm., average 0.707 mm. The puparia of 1913 in the same orchard were slightly larger; 13, measured July 28, averaged in length 1.706 mm. and in width 0.778 mm.

SECOND MOLT OF THE MALE.

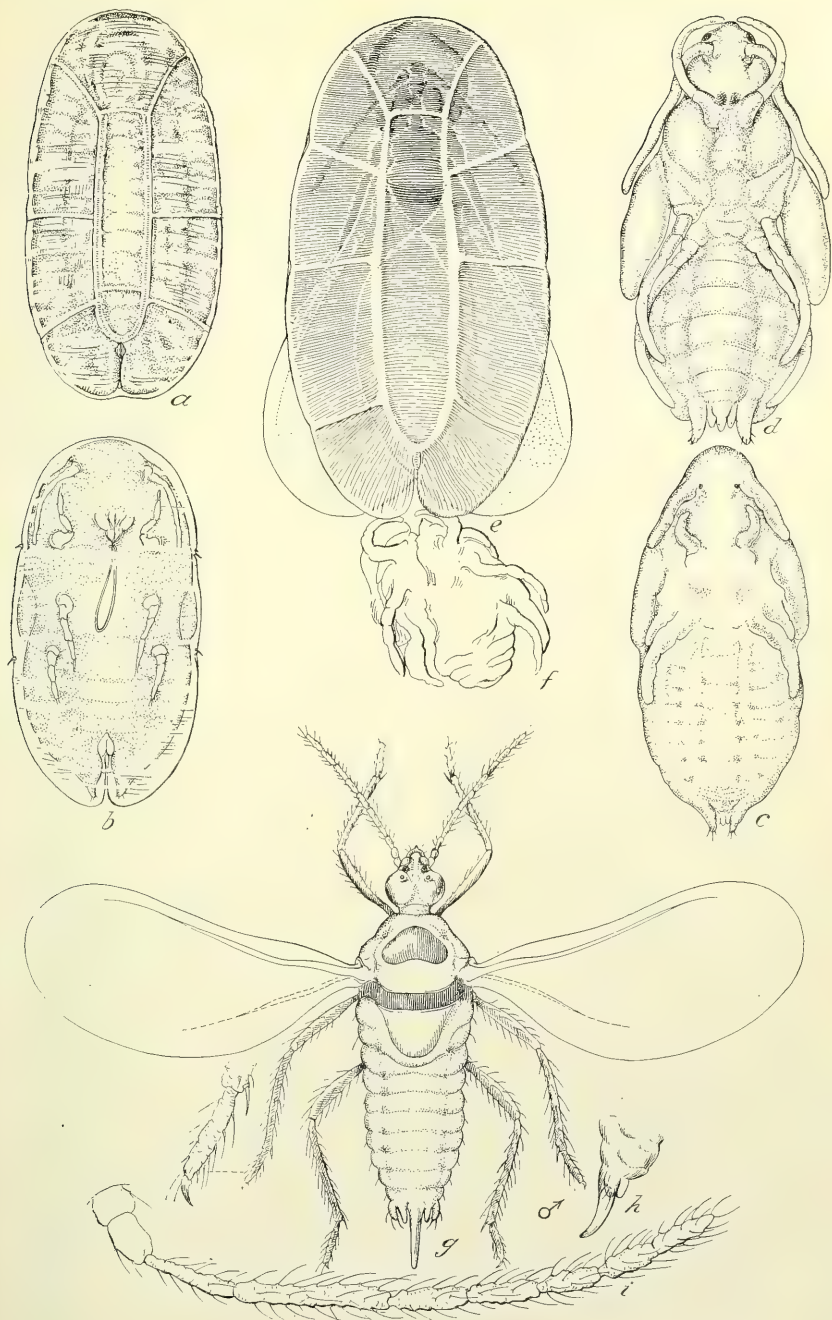
In 1912 the second molt was made by orchard larvæ from the thirty-eighth to the forty-third day, with its maximum upon the forty-first day, after emergence from the brood chamber. In 1913, with a more favorable season, this molt was made by orchard larvæ upon the thirty-sixth day. Since the larvæ entered the second instar upon the eighteenth day, they averaged 18 days in the second instar. Two rearings were made in 1913, the first from larvæ that emerged June 24 and the second from larvæ that emerged June 26. The former made their maximum daily molt for both sexes upon the thirty-seventh day, the latter upon the thirty-fourth day.

When the male larva shrinks at the end of the second instar the larval skin retains its original shape and position (Pl. II, *b*). This leaves the larva nearly free within. At this time a decided metamorphosis begins. The original legs, antennæ, and mouth-parts disappear and the anal lobes, which in the second instar are one-half as wide as the body and extend caudad beyond the anal plates (Pl. II, *a*), now shrink to short, narrow projections which extend only slightly beyond the anal plates. As a result of this change in the anal lobes the anal crease disappears and the anal apparatus assumes again its original position on the caudal margin. During this metamorphosis the hard portions of the mouth-parts remain attached to the larval skin and disappear at the second molt, after which all trace of the mouth-parts is lost. In the act of molting the larval skin is ruptured by contortions of the larva along the middorsal line, and in a few minutes it is worked downward and backward and is expelled at the caudad margin of the puparium, where it usually remains for a few days clamped under the puparium.

THE PREPUPA.

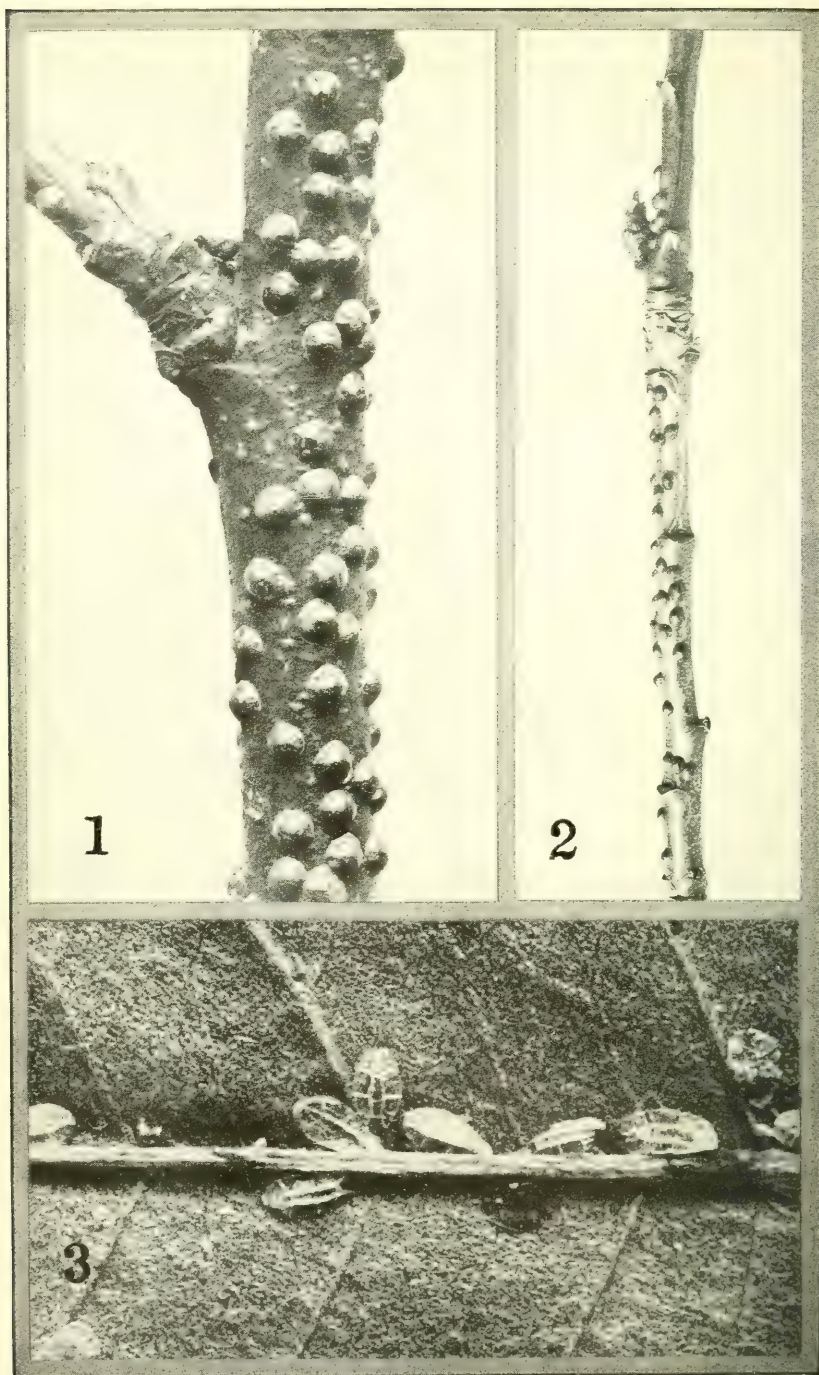
The prepupal instar is characterized by a rapid metamorphosis, which, however, actually starts before the casting of the second molt skin. The plump anal lobes of the first and second instars shrink, and the characteristic anal plates (Pl. II, *a*) are lacking. The most evident characters at the beginning of the instar are the wing-pads and the pointed anal lobes.

The prepupal period covers but 2 days, yet the metamorphosis is so rapid that decided changes occur. The wing-pads expand to their full size; the antennal sheaths expand from buds to nearly one-half of their final length, and the leg sheaths, which at the beginning of the instar were indicated by imaginal buds, become one-fourth developed. The metamorphosis of the anal region continues throughout this instar and at its end all trace of the conspicuous anal plates is lost. In their place there now project from the caudal extremity two



THE TERRAPIN SCALE.

a, The second instar under the puparium; *b*, same, shrinking in the last day of the second instar; *c*, prepupa; *d*, pupa; *e*, imago before emergence; *f*, pupa case clamped under the puparium; *g*, imago at twigward migration; *h*, lateral view of caudal extremity; *i*, enlarged antenna. All much enlarged. (Original.)



THE TERRAPIN SCALE.

FIG. 1.—Appearance of the scale on peach twig during winter; somewhat enlarged. FIG. 2.—Same, about natural size. FIG. 3.—Male puparia along midrib of peach leaf; considerably enlarged. (Original.)

fleshy lobes, between which are the sheaths of the copulatory apparatus. (Pl. II, c.) The ventral eyes are represented at the end of this instar by two brown spots.

This instar is quite constant in its length, being almost invariably 2 days. Table XXXIII gives data upon 18 males from the rearing of June 24, 1913. The average length was 2 days.

TABLE XXXIII.—*Average duration of the prepupal instar for 18 specimens of the terrapin scale, Mont Alto, Pa., 1913.*

No.	Date of second molt.	Date of third molt.	Time in prepupa.	No.	Date of second molt.	Date of third molt.	Time in prepupa.
			<i>Days.</i>				<i>Days.</i>
1.....	July 31	Aug. 2	2	11.....	July 31	Aug. 3	3
2.....	Aug. 4	Aug. 6	2	12.....	July 30	Aug. 1	2
3.....	July 31	Aug. 2	2	13.....	July 31	do.....	1
4.....	July 30	Aug. 1	2	14.....	July 29	July 31	2
5.....	do.....	do.....	2	15.....	Aug. 1	Aug. 3	2
6.....	do.....	do.....	2	16.....	do.....	do.....	2
7.....	do.....	Aug. 2	2	17.....	Aug. 5	Aug. 7	2
8.....	do.....	Aug. 1	2	18.....	Aug. 4	Aug. 6	2
9.....	Aug. 1	Aug. 3	2				
10.....	July 31	Aug. 2	2	Average.....			2

Larvæ that emerge upon the same day may vary as much as 10 days in the time required for them to reach the prepupa. The normal time of entering this instar, however, is clearly defined for most individuals. One-half of the males in any rearing will ordinarily become prepupæ upon the same date. The normal time for entering this instar in the region about Mont Alto, Pa., is upon the thirty-eighth day after emerging from under the parent scale.

Prepupæ were abundant in the orchard at Mont Alto, Pa., in 1912, from August 8 to August 20. They were present in largest numbers about August 12; after this they became gradually less abundant until August 25. After August 25 they were very scarce. At Midvale, Pa., in 1913, the first prepupæ were taken July 18. At Mont Alto, Pa., in 1913, the first prepupæ were taken July 24. This is 5 days earlier than they appeared at Mont Alto the preceding year.

Since both sexes made the second molt at the same age, and since the females migrate twigward upon the second day after this molt, it happens that the twigward migration of the females coincides with the prepupal instar of the male. In 1912 the first returned females—6 specimens in all—were taken July 29. While there were undoubtedly as many prepupæ as returned females at this time upon the trees, none was found. By August 2 the number of returned females had greatly increased and, upon this date, the first prepupæ of the season were taken.

There was a difference in 1913 of 6 days in the appearance of prepupæ at the Wertz and in the Newcomer orchards. This was due to the difference in the localities. The Wertz orchard has a strong

westward slope and is located at an altitude of 1,100 feet, with a mountain crest extending 1,000 feet above it. There is consequently a good air drainage and a partial exclusion of the sun's rays during the forenoon. The Newcomer orchard, upon the other hand, is located upon a slight knoll, with relatively level surroundings. Its altitude is less than 900 feet. Consequently the air drainage is not good and the sun's rays are unobstructed.

Four prepupæ were measured in 1912, with the following results: Length, maximum 1.29 mm., minimum 1.08 mm., average, 1.208 mm.; width, maximum, 0.618 mm., minimum, 0.562 mm., average, 0.587 mm. On April 28, 1913, 8 specimens gave the following measurements: Length, maximum 1.420 mm., minimum 1.25 mm., average 1.33 mm; width, maximum 0.6 mm., minimum 0.525 mm., average 0.559 mm.

THIRD MOLT.

The prepupa starts the third molt by a series of convulsive movements which cause the dorsal skin to split over the thoracic region. The skin is loosened and removed almost entirely by extending and contracting the abdomen. The extension thrusts cause a tension upon the ventral part of the molt skin which draws the head downward and under. This causes the dorsal thorax to protrude through the split in the molt skin. This tension increases with each thrust of the abdomen, so that the head is drawn farther and farther downward and backward until it finally slips free from the skin. The larva then assumes its regular position. In stripping the molt skin from the legs and antennæ the thrusting movements of the abdomen are aided by the puparium, which, owing to its attachment with elastic bands, yields to the molting movements and serves as a clamp to hold the skin in place while the abdomen contracts for the next thrust. The thrusting movements of the abdomen usually cease before the skin is completely expelled from under the puparium. Because of this the cast skins are mostly found clamped under the posterior end of the puparium.

The duration of this molt varies with the temperature at the time of molting and also with the vigor of the specimen. The molt usually starts in the forenoon with the resumption of the daily activity. The average time for this molt is less than an hour. Upon days when the temperature reaches 70° F. before 9 a. m., practically all the molts for the day will be completed by 10 a. m. At low temperatures many specimens die without completing it. Some specimens kept in the laboratory where the temperature did not rise above 70° F. required 18 hours for this molt. They started molting about 4 p. m. and became dormant before completing it. These molts were completed the following day.

THE PUPA.

The pupal instar is one of development. In it the rudimental structures of the preceding instar reach their full development. The leg sheaths are mere tubes at the beginning of the instar; at the end they contain the matured legs. The wing sheaths have a similar history, being at first transparent bags, which develop gradually until the last third of the instar, when the wings fold and the characteristic fleshy color appears. The pupa (Pl. II, *d*) has a pale flesh color with chitinized areas upon the head and anal region. There is also a crescent-shaped spot and a transverse band of a bright flesh color. The antennæ and legs are at first ventral, but they elongate and finally appear prominently in the dorsal view.

TIME IN PUPA.

The pupal instar varies in length, occupying from 4 to 11 days, and averages about 6 days in favorable weather. Those individuals that spend only 4 days in this instar have invariably been delayed as prepupæ. It is very exceptional for a male to pass 8 days in the pupa, even when weather conditions are unfavorable. When conditions are such that the pupæ require over 9 days, there is a heavy mortality. Many die, and those that enter the adult stage mostly die without leaving the protection of the puparium.

In both 1912 and 1913 rearings were made to determine the length of the pupal period under varying conditions. Observations made upon the specimens in the orchard showed that most of the specimens remained in the pupa 6 days. A brood that emerged July 22, 1912—that is, approximately a month after the height of the normal emergence—was retarded 6 days by unfavorable conditions. Thirteen males passed successfully through the pupal stage and gave an average of 8.15 days in the pupal instar.

The average mean temperature for July, August, and September-1912, was 71.5° F.

A brood that emerged June 24, 1913—that is, approximately at the height of emergence—passed through the larval instars in a normal manner, and the imagos left the puparia upon the forty-sixth day. These specimens were slightly retarded, owing to their removal while in prepupa from the orchard to the laboratory. Fourteen of these specimens passed through the pupal instar in a normal manner. They gave an average of 6.2 days for the pupal instar. The fraction of a day in excess of 6 days is small and is clearly due to the unfavorable environment of the laboratory. Table XXXIV gives the individual record of these 14 males. The average mean temperature for June, July, and August, 1913, was 73.4° F.

TABLE XXXIV.—*Length of the pupal instar of the terrapin scale for larvæ that emerged June 24, 1913, Mont Alto, Pa.—Conditions favorable.*

No.	Date entered.	Date left.	Pupal stage.	No.	Date entered.	Date left.	Pupal stage.
			<i>Days.</i>				<i>Days.</i>
1.....	Aug. 2	Aug. 10	8	9.....	Aug. 2	Aug. 9	7
2.....	do.	Aug. 8	6	10.....	Aug. 1	Aug. 8	7
3.....	Aug. 1	do.	7	11.....	July 31	Aug. 5	5
4.....	do.	Aug. 7	6	12.....	do.	Aug. 6	6
5.....	do.	Aug. 8	7	13.....	Aug. 3	Aug. 8	5
6.....	Aug. 2	do.	6	14.....	Aug. 1	Aug. 7	6
7.....	Aug. 1	Aug. 5	4				
8.....	Aug. 3	Aug. 10	7				
				Average.....			6.2

APPEARANCE OF PUPÆ IN THE ORCHARD.

Pupæ appear in the orchard upon the second day after the females start migrating to the twigs, and they are most abundant about the sixth day after the maximum daily migration.

At Mont Alto, Pa., 80 per cent or more of the males pass through the pupal state during the first half of August.

SIZE OF PUPÆ.

The pupæ are slightly smaller than the prepupæ, but owing to the great size of the wing-pads the pupæ average slightly wider.

Table XXXV gives measurements for 20 specimens, the first 10 of which were from 1912 and the remainder from 1913. The sizes are quite uniform for the two seasons and average 1.248 mm. long and 0.5918 mm. wide. A comparison of the prepupal and pupal measurements from the same individuals shows an average decrease in length of 0.09 mm. and an increase of 0.03 mm. in width in passing into the pupal instar.

TABLE XXXV.—*Measurements of 20 mature pupæ of the terrapin scale, Mont Alto, Pa., 1912 and 1913.*

No.	Length.	Width.	No.	Length.	Width.	No.	Length.	Width.
	<i>Mm.</i>	<i>Mm.</i>		<i>Mm.</i>	<i>Mm.</i>		<i>Mm.</i>	<i>Mm.</i>
1.....	1.2250	0.55	9.....	1.1000	0.600	16.....	1.250	0.650
2.....	1.3375	.575	10.....	1.2500	.625	17.....	1.175	.575
3.....	1.2750	.550	11.....	1.325	.625	18.....	1.275	.650
4.....	1.3000	.600	12.....	1.250	.475	19.....	1.250	.625
5.....	1.3000	.550	13.....	1.250	.650	20.....	1.250	.600
6.....	1.2500	.600	14.....	1.250	.550			
7.....	1.2500	.562	15.....	1.200	.600			
8.....	1.2000	.625				Average.....	1.2481	.5918

FOURTH MOLT.

The fourth molt, like the third, usually starts in the morning when the temperature rises to about 70° F. The first indication that a molt is about to start is a series of convulsive movements. These cause the thin pupa case to split along the anterior third of the mid-dorsal line. As these movements continue the dorsal thorax pro-

trudes more and more through this slit and the head is forced downward. Before the head escapes the anterior legs are withdrawn from their sheaths. These are the first appendages to become free. They push the case downward until the head is free. After this they force the case backward under the body. The antennal sheaths cling tightly to the antennæ and have to be stripped free from them. The middle and posterior legs take no active part in the molt, but lie motionless along the edges of the abdomen. The antennal sheaths are the last parts of the case to be shed. After the head escapes from the case it presses against the anterior end of the puparium, which serves as a fulcrum in forcing the adult free from the pupa case. Pupæ that escape by accident or are removed from under the puparium are unable to complete the molt. They continue the effort for about 24 hours and then die. In the case of weak specimens the impulse to molt often ceases before the tips of the antennæ are free. After this molt the pupal case is usually found lightly clamped under the posterior edge of the puparium. (See Pl. II, *f*.)

This molt ordinarily requires about 2 minutes for specimens at temperatures above 70° F., but at a temperature of 66° F. the time required is 5 minutes. This molt should take place about the forty-seventh day, but it is frequently delayed. For example, part of a brood that emerged August 9, 1912, was removed from the trees when in pupa. They were placed in the laboratory late in September, away from heat and sunlight, and under these conditions many of the specimens died. The remainder were abnormal and did not molt until the fifty-fifth day, or 8 days after the natural time. It was evident that a slightly longer delay would have resulted in the death of all the specimens in the pupa or during the molt.

THE ADULT MALE.

The fourth molt, like the third, is made under the puparium. The young imago at first has soft and folded wings, but these soon assume their natural shape. Several hours, however, are required for them to harden and to become fully colored. After expanding they protrude slightly from under the posterior end of the puparium and serve as a means of identifying this stage. The time spent under the puparium varies from a few hours to 4 days. The normal time for the male to remain under the puparium is from 1 to 2 days. The male regularly enters the imago in the forenoon of one day and emerges during the afternoon of the following day, but there are well-defined exceptions to this. If favorable weather has so accelerated the growth as to shorten the preceding instars, the imago tends to remain under the puparium until the regular time for emerging, but when the early instars are lengthened by unfavorable weather the imago emerges in less than 2 days.

In Table XXXVI are recorded data from 14 males that emerged late in the season of 1912. They had the fourth molt delayed to the fiftieth day and give an average of 1.36 days as the time spent under the puparium. Specimen No. 3 partly escaped from under the puparium during the fourth molt. It remained in this position for 4 hours and then emerged and started to leave the leaf.

TABLE XXXVI.—*Emergence of 14 males of the terrapin scale from a brood that made the fourth molt upon the fiftieth day, Mont Alto, Pa., 1912.*

No.	Fourth molt.		Emergence.		Time spent under puparium.
	Date.	Time.	Date.	Time.	
1.....	Sept. 5	8.40 a. m.	Sept. 6	8.40 a. m.	<i>Days. Hrs.</i> 1 0
2.....	Sept. 9	10 a. m.	Sept. 10	10 a. m.	1 0
3.....	Sept. 11	6 a. m.	Sept. 11	10 a. m.	4
4.....	do.....	6 a. m.	Sept. 14	6 a. m.	3 0
5.....	Sept. 10	2 p. m.	Sept. 12	6 a. m.	1 16
6.....	Sept. 12	6 a. m.	do.....	6 p. m.	12
7.....	Sept. 11	12 m.	Sept. 14	9 a. m.	2 21
8.....	Sept. 12	1 p. m.	Sept. 13	6 a. m.	1 17
9.....	Sept. 11	2 p. m.	do.....	6 a. m.	1 16
10.....	Sept. 12	6 p. m.	do.....	6 a. m.	12
11.....	Sept. 11	12 m.	Sept. 12	6 a. m.	18
12.....	do.....	12 m.	do.....	6 a. m.	18
13.....	Sept. 10	9 a. m.	do.....	6 a. m.	1 21
14.....	do.....	3 p. m.	do.....	6 a. m.	1 15
Average.....					1 9.07

In Table XXXVII are recorded data from 12 imagos that emerged from the brood chamber June 24 and made the fourth molt upon the forty-fifth day. They were thus normal in development. They give an average of 2 days spent under the puparium. Eight specimens from this same brood were removed from the orchard 7 days before they emerged as imagos and placed upon glass plates in the laboratory. As a result of this treatment they were delayed in the pupal stage and spent only one day under the puparium, a reduction of one-half in the time due to the changed conditions.

TABLE XXXVII.—*Emergence of 12 males of the terrapin scale from a brood that made the fourth molt upon the forty-fifth day, Mont Alto, Pa., 1913.*

No.	Date of fourth molt.	Imago emerged.	Time under puparium.	No.	Date of fourth molt.	Imago emerged.	Time under puparium.
			<i>Days.</i>				<i>Days.</i>
1.....	Aug. 10	Aug. 11	1	8.....	Aug. 10	Aug. 11	1
2.....	Aug. 8	Aug. 9	1	9.....	Aug. 8	Aug. 10	2
3.....	do.....	do.....	1	10.....	Aug. 7	do.....	3
4.....	July 7	Aug. 11	4	11.....	Aug. 5	Aug. 8	3
5.....	Aug. 8	Aug. 9	1	12.....	Aug. 8	Aug. 10	2
6.....	do.....	do.....	1				
7.....	Aug. 5	do.....	4	Average.....			2

A comparison of Tables XXXVI and XXXVII shows that the time spent under the puparium by the imago varies from 4 hours to 4 days and that the average time for normal development is 2 days.

Imagos were taken from under puparia in small numbers at Midvale, Pa., on July 27, 1913. These were the earliest specimens taken during the two seasons of observation.

EMERGENCE OF ADULT MALE.

The imago (Pl. II, *g*) usually leaves the puparium about the forty-ninth day. In 1912 the early part of the season was favorable and the imagos emerged upon the forty-ninth day, but later in the season males reared from larvæ that emerged from the brood chamber August 9 did not leave the puparium until the fifty-second day, with several specimens delayed until the fifty-eighth day. In 1913 the males emerged from the forty-third to the fifty-ninth day, with the maximum emergence upon the forty-ninth day.

DESCRIPTION OF ADULT MALE.

Length, exclusive of style, 1 mm.; style 0.15 mm.; caudal lobes 0.075 mm., being one-half as long as the paired lateral appendages; antennæ 0.6 mm.; wing, 0.44 mm. long, 0.3 mm. wide. Light flesh color in general. Head light flesh color; anterior pair of dorsal eyes reddish brown; posterior dorsal eyes similar and one-half as large; ventral pair dark brown and slightly larger than the anterior dorsal pair; antennæ whitish, 8-jointed, joint I short, thick, semiglobular; joint II slightly longer than I, claviform; joint III as long as both I and II, slender and cylindrical; the remaining joints cylindrical and subequal. Collar short cylindrical; prothorax narrow; dorsal mesothorax light flesh color, with a flesh-colored shield-shaped spot above, and terminated posteriorly by a narrow bright band of the same color; metathorax light flesh color. Wing iridescent, surface granulose, false vein through anal third; halteres none; caudal filaments none; legs and style light brown.

TWIGWARD MIGRATION OF THE MALE.

The male backs out from under the puparium and at once starts for the twigs. The wings are not ordinarily used in this migration. The insect is attracted by strong light and seems to be guided somewhat in its movements by gravity and possibly also by the scent of the female. The males leave the underside of the leaf and pass down the petiole. When the twig is reached they turn downward and examine the surface carefully as they pass over it. The antennæ are held aloft and nearly motionless, but the anterior tarsi are kept in constant motion, tapping and feeling the surface of the twigs. The males frequently in their search pass to the tips of the twigs, and in such cases they may circle the twig a few times and then return to the base and pass on, but when the illumination is strong they alight upon other twigs and start again in active search. The interval between emerging and starting the active search for the female scales is very brief, being always less than 30 minutes. The male is sexually mature when he emerges. When he approaches a female he taps upon the derm with his anterior legs, usually passing several times around the specimen in doing so, or he may conduct the examination while upon the female's back. During such an

examination the male is often diverted and may move away, but he will return, again and again, before finally abandoning his efforts. Those females that have copulated are indifferent to the male, but females of the same age that have not copulated respond by elevating and distending the anal plates. After a preliminary examination of the dorsal surface of the female the male mounts and takes the copulating position, with the head forward and the body parallel to that of the female. In the act of copulation the abdomen is curved under until the tip is in contact with the anal plates. The act of copulation requires from 2 to 10 seconds, according to the degree of exhaustion of the male. At the end of copulation the male departs and continues his search for additional mates. If by chance he returns a second time to the same female his tapplings bring no response. The male is decidedly polygamous and continues copulating with one female after another until he dies of exhaustion. The following observations were made upon a male that left the puparium September 6, 1913:

Emerged from puparium.....	9.40 a. m.
Discovered first susceptible female and copulated.....	9.42 a. m.
Discovered second female and copulated.....	9.44 a. m.
Discovered third female.....	9.46 a. m.
Discovered fourth female.....	9.50 a. m.
Discovered fifth female.....	9.56 a. m.
Died of exhaustion.....	9 p. m.

At the end of the fifth copulation detailed observations stopped, but the male continued in diligent search for more females. This individual died of exhaustion 12 hours after leaving the puparium.

The active male, when moving naturally upon the host plant, lives less than 24 hours. Almost invariably the male emerges in the forenoon, exhausts himself in copulation during the hottest portion of the day, and dies before midnight. When confined singly in test tubes they live from 1.25 to 2.75 days. Six specimens confined in test tubes gave 2.75 days as the maximum, 1.25 days as the minimum, and 1.625 days as the average longevity.

SUMMARY OF LIFE HISTORY OF THE MALE.

The male lives an average of 49 days and passes through 5 instars. In the first two instars it is a vigorous feeder, and accumulates all the energy used during the remainder of its life. The 3 remaining instars are characterized, as a whole, by the absence of functional mouth-parts and by the development of the adult organs.

The length, in favorable weather, and the distinguishing characteristics of the instars are as follows.

The feeding instars: First instar, length 18 days—vegetative; second instar, length 18 days—sexual differentiation.

The nonfeeding instars: Third instar (prepupa), length 2 days—metamorphosis; fourth instar (pupa), length 6 days—development of adult structures; fifth instar (imago) dormant phase, length 2 days—hardening of exo-skeleton; active phase, length 1 day—migration and copulation.

SEASONAL HISTORY.

There is one generation of the terrapin scale annually. This species passes the winter as immature females. At the start of hibernation these are very plump and the ventral part of the abdomen crowds against the surface of the host, so that there is no vacant space beneath the scale, but by the middle of March the abdomen has shrunk until there is a dome-shaped cavity beneath it. When the spring growth starts the specimens become plump again and the space beneath the scale disappears. Most of the specimens reach maturity during the middle of June and begin at once to produce young. The majority of the scales reproduce for a period of about one month, but an occasional female may continue actively reproducing for as long as $3\frac{1}{2}$ months. On the second day after the first young are born they begin to emerge from the brood chamber of the parent, mostly through the anal cleft. During the first 5 weeks there is a heavy migration of larvæ to the leaves. This migration reaches its maximum during the first week of emergence. It then gradually declines, until by the end of the fifth week it amounts to less than 5 per cent of the maximum emergence. (See figs. 2 and 4.) At the beginning of the sixth week after the appearance of the first young the female larvæ start migrating from leaf to twig. By the end of the seventh week the females are ready for copulation and the males migrate to the twigs. Copulation occurs at this time and the males die at once, but the females start upon a period of rapid growth, during which they excrete a vast amount of honeydew, which is responsible for most of the injury caused by this scale. After 2 or 3 weeks of extreme activity their growth gradually slackens, but it continues until cold weather forces the partly mature females into hibernation, after which they remain dormant until the following spring, dying about mid-summer after the production of young.

MORTALITY.

There is more or less mortality at all seasons of the year. Ordinarily there seems to be comparatively little due to winterkilling, though at times this may be considerable. The amount of winterkilling depends mainly upon the vigor of the host plant and upon the severity of the winter. During 1912-13, upon well-nourished trees, the mortality from this source was not more than 5 per cent of the hibernating scales. During 1913-14, however, scales upon trees of low vitality had a mortality as high as 40 per cent.

The females during the spring development are sometimes heavily attacked by hymenopterous parasites, especially species of the genus *Coccophagus*. At the start of reproduction the larvæ of the coccinellid *Hyperaspis binotata* Say (fig. 17) enter the brood chambers and attack the lecanium larvæ, while later the maturing larvæ of this beetle, in attempting to enter the brood chambers, dislodge many of the gravid females, thus destroying at once both the female and the unborn young. (See fig. 18.)

Cold, wet weather at the time of reproduction causes many larvæ to die in the brood chamber. These frequently clog the exit and prevent the egress of the remainder of the brood. This condition was especially noticeable in the season of 1912, when owing to protracted rain 5 per cent of the gravid scales were affected in this way.

During the leafward migration most of the young succeed in reaching the leaves, and the loss at this period is due mainly to drowning by sudden rains and to the dropping of larvæ from dead twigs. During the leaf phase the larvæ are often heavily attacked by predatory enemies, but the female larvæ are practically free from parasitic attack, and the males are but slightly attacked. However, after returning to the twigs the females are subject, at times, to a heavy parasitic attack which may cause a mortality as high as 20 per cent. They are also subject to attack at this time by a pyralid moth, *Laetilia coccidivora* Comst. In conclusion it may be said that the mortality from weather conditions throughout the year is not more than 50 per cent, and that in favorable seasons it is almost negligible.

ATTENDANTS.

The terrapin scale excretes a honeydew which is very attractive to ants, and during the time in which it is being deposited all the species of ants in the vicinity will be found working upon it, while at other seasons no ants will be about. In the early spring, when the fruit buds are about to burst into bloom, considerable honeydew is excreted and ants are then actively working, but during the period of reproduction very few ants appear. When, however, the twigward migration of the females starts, the ants return and remain in almost constant attendance until the scale hibernates. There is no species of ant that habitually attends this scale, but most of the orchard ants feast upon its bounties. Only slight benefit to the scale results from the attendance of the ants. Some of them are pugnacious and undoubtedly tend to ward off predators and to frighten away and confuse parasites.

The following four species taken at Mont Alto, Pa., attending this scale were identified by Dr. W. M. Wheeler:

Formica truncicola Nyl. subsp. *integra* Nyl.

Formica fusca L. var. *subsericea* Say.

Lasius niger L. var. *americanus* Emery.

Prenolepis imparis Say.

PREDACEOUS ENEMIES.

At Mont Alto, Pa., in 1912, the lacewing fly *Chrysopa nigricornis* Burm. made an attack during the twigward migration which was unimportant, although it continued until the larvæ migrated to the twigs. This species was reported in 1893 by Mary E. Murtfeldt as actively attacking the larvæ of this lecanium.

Larvæ of *Hemerobius stigmaterus* Fitch were present in 1912 in considerable numbers and the result of their attack was quite noticeable.

The predaceous pyralid *Laetilia coccidivora* Comst. was present in 1913, and its larvæ made a very vigorous attack. The eggs were placed singly among the scales upon infested twigs, apparently during the first half of June, and hatched in about 6 days. The larva is greenish black, with a black, slightly bilobed head, and feeds within a delicate silken tube which it constructs from scale to scale as it advances along the twig. It first attacks the gravid females, and hundreds of their empty derms can often be seen clinging to one another and to the silken tubes upon trees where it has fed. When the larva reaches its full development it spins a cocoon within the silken tube, usually near the axil of a bud or at the base of a fruit spur. *L. coccidivora*, at Midvale, Pa., requires about 10 days to pass through the pupal stage. The imago emerged from their cocoons during August and deposited their eggs upon the twigs among the young scales, which were at that time migrating to the twigs. The larvæ of this second brood made a vigorous attack upon the young females. This predator is aggressive and under favorable conditions can undoubtedly control this scale. The author observed its work during the season of 1913, in the orchard of Mr. A. Newcomer, near Midvale, Pa. It was, however, heavily parasitized, and so made very little impression upon its host. Two species of parasites were reared in abundance from this pyralid at Midvale, Pa. They were *Mesostenus thoracicus* Cress. and an undescribed species of *Habrobracon*.

The predatory bug *Camptobrochis nebulosus* Uhl., although not found at Mont Alto, Pa., was reported by Mary E. Murtfeldt as preying upon the active larvæ of this lecanium at Kirkwood, Mo., in 1893.

Species of Coccinellidæ of the genus *Hyperaspis* are undoubtedly the most efficient agents in the control of this lecanium. Miss Murtfeldt, in reporting upon *Hyperaspis signata* for 1893, says: "The flocculent larvæ of this coccinellid were very numerous and active among swarming larvæ of *L. nigrofasciatum* but were not found upon any other coccid or aphid during the season."

Mr. A. B. Gahan, in Maryland Agricultural Experiment Station Bulletin 149, mentions the attack by ladybirds and says: "* * * the species most commonly observed being the twice-stabbed lady-

bird, *Chilocorus bivulnerus*." The writer has occasionally taken the adults of this species, which is scarce about Mont Alto, Pa., upon trees infested with the terrapin scale, but has never observed either it or its larvæ preying upon this scale.

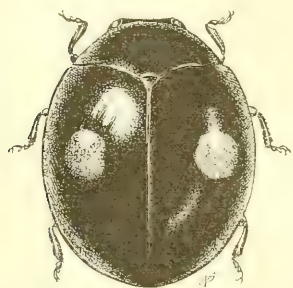


FIG. 17.—A predaceous enemy of the terrapin scale, *Hyperaspis binotata*. Much enlarged. (Original.)

At Mont Alto, Pa., there was, in 1912 and 1913, a heavy and effective attack by *Hyperaspis binotata* Say. This ladybird was taken abundantly in the orchard of D. M. Wertz in 1912 and was very abundant there and in adjacent orchards during the following year. It was also taken in considerable numbers during 1913 at the Newcomer orchard near Midvale, Pa. This ladybird worked so effectively at Mont Alto, Pa., as nearly to exterminate a very severe infestation. *H. binotata* (fig. 17) differs somewhat from the common species of ladybirds, both in its habits and life history. The adult beetles hibernate under bark and in rubbish and become active in early spring. They feed upon

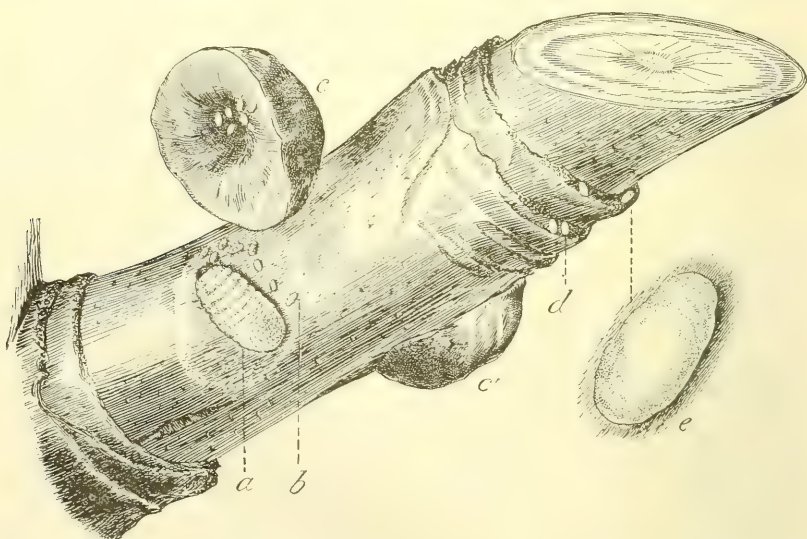


FIG. 18.—Eggs and a second-instar larva of *Hyperaspis binotata* as it appears under a displaced scale; *a*, Second instar as disclosed by displacing the host; *b*, larvæ of the terrapin scale; *c*, a displaced scale; *d*, eggs of the predatory beetle *Hyperaspis binotata* in situ; *e*, egg, highly magnified. All much enlarged. (Original.)

honeydew and upon aphides during the early part of the season but are unable to attack the lecanium in the spring because of its hard derm. They feed upon it readily when the derm is crushed.

The eggs, which are a salmon color, are deposited singly upon the twigs, a favorite place being upon the ringlike scars that mark the limit of the seasonal growth. (Fig. 18, *d*, *e*.) The eggs are too small to be seen readily by the unaided eye. They commence to hatch about the middle of May and the young seek the mature scales and enter their brood chambers by way of the anal cleft. When once within the brood chambers they prey upon the newborn young. The ladybird larvæ make their first molt within this brood chamber and continue to feed until the end of the second instar; by this time the *Hyperaspis* larvæ are so large that they crowd the brood chamber and often displace their host. Finally the larvæ leave the host and make the second molt, usually at the base of a fruit spur, and then attack other scales, which they do by forcing their heads under the margin and displacing them. In this manner they continue through the third and fourth instars, each larva destroying many gravid scales. When all the gravid females are destroyed the *Hyperaspis* larvæ, which are then mostly in the fourth instar (fig. 19), migrate to the leaves and continue their feeding upon such of the larvæ as have reached the leaves. Afterwards the ladybird passes the pupal stage in a pupa case attached to the leaves or to the twigs, and sometimes in cavities under the bark. Most of the hibernating beetles die before the first brood emerges from the pupa.

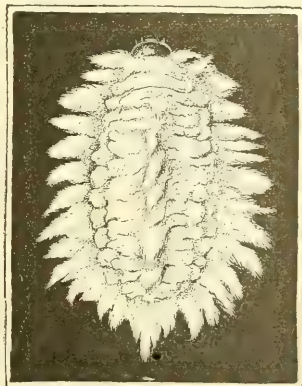


FIG. 19.—The fourth-instar larva of *Hyperaspis binotata* as it appears when attacking the larvæ of the terrapin scale. Much enlarged. (Original.)

PARASITES.

The terrapin scale is heavily parasitized, and this parasitism is mostly confined to the female, though the male is slightly attacked. The first and second instars are very free from parasites, but a heavy attack starts soon after the young females have attached to the twigs. This attack increases in violence until checked by the approach of winter. Most of the parasites pass the winter within the host and emerge early in the season to make a new attack, which reaches its maximum just before the scales begin producing young.

Coccophagus lecanii Fitch was the most abundant species reared in 1912, but *C. cognatus* Howard was also abundant, especially in the fall. In 1913 *C. lecanii* Fitch was rare. In its place *C. cognatus*

appeared in large numbers and attacked the developing females in the spring. That which was apparently the first brood emerged from the hosts about June 30. This infestation was very noticeable owing to the excessive blackening of the scales, as from 20 to 50 per cent of the scales were killed. Later this same species made an attack upon the male larvæ when in the second instar, and in some instances 5 per cent of the males were destroyed. At Ledy Station, Pa., and at Midvale, Pa., this species made a heavy attack in the fall, but at Mont Alto, Pa., it was scarce, owing to the almost complete destruction of the host by *Hyperaspis binotata*.

Aphycus stomachosus Gir. was the most abundant parasite in 1913, being more numerous than *C. cognatus*. It was reared in greatest numbers from the nearly mature females in the early part of June, but it was also taken in large numbers in the orchards during the first half of September. *Aphycus johnsonii* Howard was reared in small numbers from both *Eulecanium nigrofasciatum* Pergande and *E. corni* Bouché at Mont Alto, Pa., but the last-named species seemed to prefer *L. corni* as a host.

Besides the foregoing parasites, *Blastothrix sericeae* Dalman was reared from *E. nigrofasciatum* in 1912, as well as numerous specimens of a new genus of Encyrtidæ.

A number of specimens of *Prospalta* sp. were taken from the parasite cages during the season of 1912, but these may have come from armored scales that were introduced by accident.

The records of this bureau contain references to the following species as parasites of *Eulecanium nigrofasciatum*:

Coccophagus ater How.

cognatus How.

lecanii Fitch.

cinguliventris Gir.

longifasciatus How.

flavoscutellum Ashm.

fraternus How.

Aphycus annulipes Ashm.

johnsoni How.

stomachosus Gir.

Anagrus nubilipennis Gir.

Eunotus lividus Ashm.

Pachyneuron altiscuta How. (secondary).

Prospalta aurantii How.

Chiloneurus albicornis How.

Blastothrix sericea Dalm.

Comys fusca How.

SOOTY MOLDS.

Eulecanium nigrofasciatum does most of its damage to the peach through its mold-infested honeydew, which is deposited in varying amounts throughout the entire season. While this honeydew is objectionable, it would cause very little damage were it not for the sooty molds which grow abundantly on the leaves, twigs, and fruit and on the soil beneath the trees when these are coated with the honeydew. This honeydew becomes noticeable only at three times during the year. A slight deposit from the maturing females appears in

April and May, and another in July from the leaf-attached larvæ; but neither of these deposits is sufficient to do much damage. The really important deposit starts about August 10, at the time when the females attach to the twigs, and continues until the approach of cold weather. The amount of sooty mold produced is limited apparently only by the amount of honeydew excreted. The mold becomes noticeable during the first week in July as black streaks which first appear in the depressions on the upper surface of the leaves. It gradually increases in amount until the middle of August, and from this time until the middle of September the increase is very rapid. The infestation is at its worst about the middle of September, at which time fruit, foliage, and branches are covered with a sticky black slime. The extent of the injury depends upon the degree of infestation and upon the time of ripening of the fruit. Late varieties are damaged most by the mold-infested honeydew, as it shows worse upon fruit which ripens after the middle of August.

REMEDIAL MEASURES.

At the beginning of this investigation lime-sulphur was known to be ineffective and kerosene emulsion was considered unsatisfactory in the control of the terrapin scale. The so-called miscible oils (proprietary emulsifiable oils), however, were believed to be reasonably efficient when properly employed, though it was believed that there was more or less danger to the trees and fruit buds from their use.

For convenience in treatment the materials used in these experiments are considered in groups. In all 62 experiments were performed, most of them in the orchard of D. M. Wertz, at Mont Alto, Pa. The others were at Midvale, Pa., and at Washington, D. C.

A consideration of the life history of this scale shows that it can be attacked both in the larval and the adult stages. The adult stage, owing to its long duration and accessibility, obviously offers the more favorable opportunity for treatment. During the first season sprayings were made against both the larva and the adult.

OIL SPRAYS.

Experience shows that all oil sprays are most effective when applied as a fine mist and under strong pressure. All oils were applied with disk nozzles of the Vermorel type, having apertures of one-sixteenth inch. The oils noted in Table XXXVIII, all of which were applied in the spring after the buds had started to swell but before they had opened, proved to be inefficient. These oils were emulsified as follows:

Oil.....	2 gallons.
Soap (hard).....	$\frac{1}{2}$ pound.
Hot water.....	1 gallon.

The soap was dissolved in the water and to this the oil was added. The whole was churned through a spray pump until no free oil remained. The emulsion was then diluted to the required strength and applied.

Figure 20 shows that portion of the Wertz orchard in which most of the experimental work was done. The orchard is in apples, interplanted mostly with Smock and Chair's Choice peaches. The trees were 11 years old in 1912 and very vigorous. At the beginning of the investigation these trees were grouped into 14 major plats, as shown in the figure. The check plats were used as such until a better method of checking was devised, when they were subplatted and sprayed. Most of the checking was done by scale counts from tagged branches upon special check trees left within the plats.

The rosin-oil emulsion was very efficient so far as killing scales was concerned. This oil dried rapidly, the trees soon appeared as if covered by a varnish, and the scales died almost at once. Unfortunately this oil gave very severe spray injury and some of the trees were so severely damaged that they required drastic pruning and stimulation to save them. While the spray injury could have been lowered by reducing the amount of oil, it was not thought advisable to continue the experiments.

The corn oil, which was also used as a 20 per cent emulsion, was equally good as a scale killer but formed a waxy scum over the branches and penetrated deeply into the tree, causing the death of many large limbs. These trees required drastic pruning and stimulation, but the injury was not so severe as in the case of the rosin oil. It was, however, too severe to justify its further use.

The gasoline, which was used as a 10 per cent emulsion, had a very low efficiency as a scale treatment but gave promise in other ways, as it readily dissolved the wax film which protects the scale from water, and it caused the scales to loosen temporarily from the bark. After the emulsion evaporated, however, the scales soon resumed their normal condition. This emulsion produced no spray injury.

MISCIBLE OILS (PROPRIETARY EMULSIFIABLE OILS).

In order to secure data for the better understanding of the factors that enter into the successful use of miscible oils the sprayings enumerated in Table XXXIX were made.

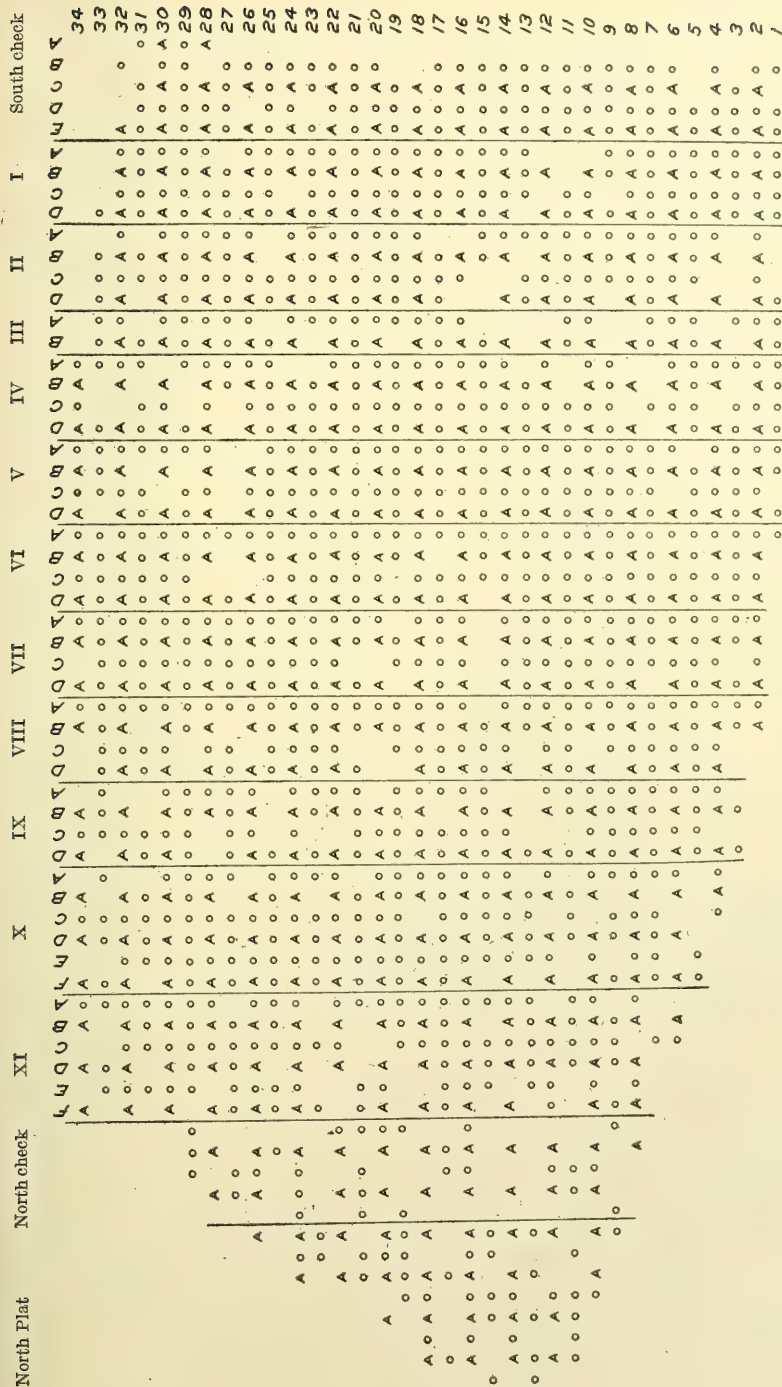


Fig. 20.—Map of the experimental plats in the D. M. Wertz orchard, Mont Alto, Pa. (Original.)
A, Apple trees.
o, Peach trees.

TABLE XXXVIII.—Data from plats sprayed with rosin-oil, corn-oil, and gasoline emulsions for the terrapin scale.

Plat.	Experiment No.	Number of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.				Spray injury.	
							Date.	Total.	Dead.	Living.		Per cent dead.
VII D.....	1	11	Years. 11	Heavy.	{Rosin oil, 20 per cent emulsion.	Apr. 11, 1912, dormant.	{Apr. 15, 1912 May 2, 1912	100 100	98 98	2 2	98 98	Very severe. Do.
	2	11	11	...do....	{Corn oil, 20 per cent emulsion.	do.....	{Apr. 20, 1912 Apr. 18, 1912 May 5, 1912	100 800 100	98 800 98	2 0 2	98 100 98		Slight. Do. Very severe.
Washington, D. C.....	3	1	2	...do....	Gasoline, 10 per cent emulsion.	Mar. 12, 1913, dormant.	Mar. 20, 1913	100	10	90	10	None.

TABLE XXXIX.—Data from plats sprayed with miscible oils for the terrapin scale, seasons of 1912 and 1913.

Plat.	Ex- peri- ment.	Num- ber of trees.	Age.	Degree of infesta- tion.	Formula.	Application.	Scale count.						Per cent dead in checks.	Final result.
							Date.	Total.	Dead.	Living.	Per cent para- sitized.	Per cent dead.		
1912.	North plat.	1	40	Heavy	Miscible oil, 1 part; water, 18 parts.	Apr. 11, 1912	Apr. 15, 1912	200	180	20	0	90	0	Efficient.
		2	16	do.	do.	Dec. 23, 1912	Mar. 18, 1914	100	85	15	0	85	0	Inefficient.
	XI.	3	100	Moderate	do.	Mar. 29, 1913	{ Apr. 23, 1914 May 2, 1914	1,081 1,725	848 1,062	233 663	0 0	78.45 61.57	0	Do.
		4	17	Heavy	Miscible oil, 1 part; water, 16 parts.	Dec. 23, 1912	Mar. 18, 1914	100	85	15	0	85	0	Do.
	South check, c.	5	28	do.	Miscible oil, 1 part; water, 20 parts.	do.	Mar. 18, 1913	100	70	30	0	70	0	Do.
	South check, b.	6	30	do.	Miscible oil, 1 part; water, 24 parts.	do.	do.	246	133	113	0	46	0	Do.
	South check, a.	7	16	do.	Miscible oil, 1 part; water, 30 parts.	do.	do.	100	15	85	0	15	0	Do.
1913.	X f.	8	17	do.	{ Miscible oil, 1 part; water, 16 parts.	Mar. 29, 1913	{ Apr. 22, 1913 May 2, 1913	951 1,072	769 981	182 91	0 0	80.90 91.52	10	Efficient.
	X c, d, e.	9	55	do.	{ Miscible oil, 1 part; water, 20 parts.	Mar. 28, 1913	{ Apr. 25, 1913 May 19, 1913	292 1,033	265 928	27 105	0 0	90.76 89.84	10	Do.
	X c, d, and X a.	10	75	do.	Miscible oil, 1 part; gasoline, 1 part; water, 18 parts.	do.	May 20, 1913	2,419	1,875	544	10	77.57	10	Do.
	IX a, b, and X d.	11	65	do.	Miscible oil, 1 part; gasoline, 1 part; water, 20 parts.	do.	May 21, 1913	2,432	1,967	465	10	80.28	10	Do.
	VII d and VIII b.	12	60	do.	Miscible oil, 1 part; gasoline, 1 part; water, 20 parts.	do.	do.	1,120	936	184	10	83.57	10	Do.
	VII a, c.	13	45	do.	Miscible oil, 1 part; gasoline, 1 part; water, 28 parts.	do.	May 9, 1913	685	139	546	10	20.30	10	Inefficient.
	Midvale, Pa.	14	200	do.	Miscible oil, 1 part; gasoline, 3 parts; water, 92 parts.	Nov. 6, 1913	Mar. 31, 1914	1,784	1,142	642	0	64.01	55.01	Moderately efficient.

1 The apparent discrepancy between the per cent dead and the final estimate is due to the falling of dead scales in the interval between spraying and counting.

In all cases the plats were first carefully inspected and typical branches were marked with tags which stated the condition of the scales and the nature of the infestation. About 10 per cent of the tagged trees were then left unsprayed and the results were taken by an individual examination of the scales upon the tagged branches. Before taking the scale count all winter killed and parasitized scales were removed from the branches, so that the count includes only scales that were alive and normal at the time the sprayings were made. The result of miscible-oil sprays became evident in a very few days after the application, when the dead scales began to drop. Because of the dropping of the scales it was found that counts should be made within one week after the application to show the true mortality. The result of delaying the count is well illustrated by a comparison of experiments 1 and 2. So far as the counts show these applications were equally effective, but in the second experiment there was an interval between the application and the count, and some of the dead scales had disappeared, thus making the mortality appear lower than it was. In comparing experiments 1 and 2, it appears that miscible oil at the strength of 1 gallon of oil to 18 gallons of water, when applied in the spring, is moderately effective against the scale, without producing injury to the trees, and that when applied in the fall it is nearly as effective against the scale, but produces severe injury to the trees.

Experiment 3 was made to determine the effect of using the regular lime-sulphur nozzles in applying miscible oil, and the plat was sprayed by the regular orchard force without oversight. Of the two counts made in experiment 3, the first represents the true mortality and the second shows only the condition of the scales present on May 2, when there were fewer dead scales than on April 23, due to their falling in the interval between the counts. The results in experiments 1 and 3 show clearly the necessity for using nozzles with smaller apertures and for making a more thorough application than is customary when applying dormant lime-sulphur sprays.

Experiments 4, 5, 6, and 7 show the effects of applying miscible oil in the winter, at a time when both the lecanium and the trees are dormant. When these applications were made the day was mild and calm, with the temperature well above freezing. A power outfit was used and the trees were sprayed until there was a slight dripping from the branches. The time between the date of applying these sprays and the date of making the scale count was rather too long to give the full mortality. The error, however, was small and was estimated at less than 5 per cent. These four experiments were all ineffective. Experiment 4 was accompanied by severe injury and experiments 5, 6, and 7 showed spray injury and failed to control the scale. It is therefore concluded that miscible oils are

not satisfactory when applied against the terrapin scale in the winter season.

In the spring of 1913 6 sprayings were made to test the efficiency of commercial miscible oils to which a wax solvent had been added. Accordingly experiments 8, 9, 10, 11, 12, and 13 were made and the sprays were applied in connection with the sprayings in experiments 1 to 7. It is to be noted that the spray used in experiment 8 was quite effective as a scale destroyer and that only a small amount of spray injury resulted. It serves, by contrast with experiment 4, to show that oils which are dangerous and ineffective when applied in winter may be applied with success in the spring. Particular attention is called to the effective work done by miscible oil when used at the rate of 1 gallon to 20 gallons of water in experiment 9. Where gasoline was added to the miscible oil there was a decided loosening of the scales, and many of the dead scales fell before the count was made, while comparatively few fell where miscible oil was used alone. This condition was noticed at the completion of the count, and comparisons were then made of the number of living scales in the plats having miscible oil only, in contrast with those having both miscible oil and gasoline, with the result that in all cases fewer living scales were found upon the twigs treated with the spray containing gasoline than upon those having miscible oil alone. It is therefore concluded, regardless of the count, that miscible oils are improved as a spray by the addition of gasoline emulsion.

Experiment 14 was made in Mr. A. Newcomer's orchard near Midvale, Pa., November 6, 1913, to determine the effect of a miscible oil and gasoline mixture when applied in the fall just after the leaves had fallen, and 15 trees were sprayed for comparison with the same percentage of miscible oil, but without gasoline. Unfortunately it was not possible to make a scale count until March 31, 1914, when many of the dead scales had fallen. Infested limbs upon the check trees were compared with similar branches on the trees in experiment 14, and these comparisons showed that the formula was more effective with gasoline than without it. The spray injury in this experiment was slight and the treatment was moderately efficient. All of the experiments made March 28 and 29, 1913, were finally rated as efficient, except No. 13, where the spray was deficient in oil. It is the author's belief that miscible oil—while not as desirable as linseed-oil emulsion, which is treated later—can be used with safety when applied just before the buds open, in dilutions of 1 gallon in 16 to 20 gallons of water. It is very effective, especially when the oil is mixed with one-half its volume of gasoline (emulsified). The natural mortality in the Newcomer orchard for the winter of 1913-14, as determined by a scale count from unsprayed trees, was 55.01 per cent.

COTTONSEED OIL.

The 10 experiments summarized in Table XL were made with cottonseed oil during 1912 and 1913. This oil was emulsified in all cases exactly as kerosene oil is emulsified in the preparation of kerosene emulsion. The sprays were applied in experiments 3, 4, 5, 6, and 7 with a hand sprayer and the applications were so thoroughly made that every scale was covered. The sprays in the other experiments were applied with a power sprayer.

TABLE XL.—*Experiments with cottonseed-oil emulsions against the terrapin scale.*

Plat.	Ex- peri- ment No.	Trees.	Age.	Degree of infesta- tion.	Formula.	Application.	Spray in- jury.	Final result.	Scale count.					Per cent dead in check.
									Total.	Dead.	Living.	Per cent parasit- ized.	Per cent dead.	
VIII a, east end.	1	11	Yrs. 11	Very heavy	Cottonseed oil, 20 per cent.	Apr. 11, 1912, dormant.	{Slight. Severe.	{Inefficient.	800	800	0	0	100	0
I d, east end.	2	7	11	do.	Cottonseed oil, 18 per cent.	Nov. 9, 1912, dormant.	{do.	{do.	200	188	12	0	94	0
A, Washing- ton, D. C. ¹	3	1	2	Heavy	Cottonseed oil, 10 per cent.	Jan. 23, 1913, dormant.	{do.	{do.	100	100	0	0	100	0
B, Washing- ton, D. C.	4	1	2	do.	Cottonseed oil, 5 per cent.	Jan. 30, 1913, dormant.	{None. do.	{Very efficient.	300	300	0	0	100	0
C, Washing- ton, D. C.	5	2	2	do.	Cottonseed oil, 2.5 per cent; gasoline, 2.5 per cent; water, 95 per cent.	Mar. 15, 1913, dormant.	{do.	{do.	200	190	10	0	95	0
D, Washing- ton, D. C.	6	1	2	do.	Cottonseed oil, 1.5 per cent; gasoline, 3.5 per cent; water, 95 per cent.	Mar. 15, 1913, dormant.	{do.	{do.	200	190	10	0	95	0
E, Washing- ton, D. C.	7	1	2	do.	Cottonseed oil, 10 per cent; gasoline, 5 per cent; water, 85 per cent.	Mar. 19, 1913, dormant.	{Severe.	{do.	218	215	3	0	98.63	0
VI, a, b, c ² ...	8	28	12	do.	Cottonseed oil, 2.5 per cent; gasoline, 2.5 per cent; water, 95 per cent.	Mar. 29, 1913, dormant.	{None.	{Efficient.	1,849	1,682	167	0	90.97	0
VI, d ² ...	9	16	12	do.	Cottonseed oil, 5 per cent.	Mar. 28, 1913, dormant.	{do. Very slight.	{Inefficient.	1,015	512	503	0	50.44	0
Midvale, Pa. ²	10	90	12	do.	Cottonseed oil, 5 per cent; gasoline, 3 per cent; water, 92 per cent.	Nov. 5, 1913, dormant.	{None. do.	{Efficient.	1,526	615	875	0	42.46	0
									100	85	15	0	85	21
									100	90	10	0	90	

¹ This tree died from spray injury. ² These counts represent less than the maximum efficiency of the spray, owing to the dropping of killed scales before the date of counting.

TABLE XLI.—*Experiments with raw linseed-oil emulsions against the terrapin scale.*

Plat.	Ex- peri- ment No.	Num- ber of trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Spray injury.	Final result.
							Date.	Total.	Dead.	Living.	Pari- tized.	Per cent dead.	Per cent dead in check.	
VIII b.....	1	11	Y ⁷⁸ . 11	Heavy.....	Linseed oil, 20 per cent emulsion.	Apr. 5, 1912, dormant.	Apr. 20, 1912 June 28, 1912	123 100	115 98	8 2	0 0	93.49 98	0 0	Mod- erately severe.
Washington, D. C.	2	1	2	do.....	Linseed oil, 10 per cent emulsion.	Mar. 19, 1913, dormant.	July 17, 1912 Mar. 24, 1913	100 100	98 100	2 0	0 0	98 100	0 0	Inefficient. Very efficient.
V d.....	3	11	12	do.....	Linseed oil, 5 per cent emulsion.	Mar. 28, 1913, dormant.	Apr. 25, 1913	722	601	121	0	83.24	0	do.....
V b, c.....	4	22	12	do.....	Linseed oil, 2.5 per cent; gasoline, 2.5 per cent.	Mar. 28, 1913, dormant.	May 28, 1913	889	728	161	0	81.89	0	do.....
Midvale, Pa..	5	200	12	do.....	Linseed oil, 5 per cent; gasoline, 3 per cent.	Nov. 5, 1913	Mar. 30, 1914	1,489	1,489	0	0	100	54.74	Very efficient.

TABLE XLII.—*Data from plats sprayed with mixed oils for the terrapin scale.*

Plat.	Ex- peri- ment No.	Trees.	Age.	Degree of infesta- tion.	Formula.	Application.	Scale count.						Spray injury.	Final results.
							Date.	Total.	Dead.	Living.	Per cent para- sitized.	Per cent dead.	Per cent dead in check.	
III d.....	1	22	Y ⁷⁸ . 12	Heavy.....	Raw linseed oil 2½ parts, cotton- seed oil 2½ parts, water 95 parts.	Mar. 28, 1913	May 29	1,840	1,334	506	0	72.83	0	Inefficient.
IV a.....	2	11	12	do.....	Raw linseed oil 1½ parts, cottonseed oil 1½ parts, gaso- line 2½ parts, water 95 parts.	do.....	May 28	1,639	874	765	0	53.33	0	Do.

TABLE XLIII.—*Experiments against the terrapin scale with sprays containing nicotine as the active ingredient, Mont Alto, Pa.*

Plat.	Ex- peri- ment No.	Trees.	Age.	Degree of infesta- tion.	Formula.	Application.	Scale count.								Final results.
							Date.	Total.	Dead.	Living.	Per cent para- sitized.	Per cent dead.	Per cent dead in check.	Spray injury.	
IV.....	1	73	Yrs. 11	Heavy....	Nicotine sulphate 1 part, 3 per cent kerosene emul- sion 400 parts.	Apr. 5, 1912, dormant.	Apr. 20	175	25	150	0	14.3	0	None....	Inefficient.
VI.....	2	93	11	...do.....	Nicotine sulphate 1 part, 10 per cent lime-sulphur so- lution 400 parts.	do.....	do.....	186	24	162	0	13	0	...do.....	Do.
VII.....	3	88	11	...do.....	Nicotine sulphate 1 part, 1.6 per cent miscible-oil emulsion 400 parts.	do.....	do.....	100	30	70	0	30	0	...do.....	Do.
V.....	4	90	11	...do.....	Tobacco extract 1 part, 3 per cent kerosene emul- sion 20 parts.	do.....	May 24	200	23	177	0	11.5	0	...do.....	Do.
North check..	5	34	11	...do.....	Nicotine sulphate 1 part, 3 per cent kerosene emul- sion 400 parts.	Aug. 6, 1912, twigward migration.	Aug. 16	300	55	245	0	18.3	0	...do.....	Do.
II c, d.....	6	40	11	...do.....	Nicotine sulphate 1 part, 3 per cent kerosene emul- sion 400 parts.	Aug. 22, 1912, young fe- males upon the twigs.	Sept. 16	100	50	50	0	50	0	Severe..	Do.
II a.....	7	12	11	...do.....	Tobacco extract 1 part, 3 per cent miscible-oil emulsion 20 parts.	do.....	Sept. 13	100	60	40	0	60	0	...do.....	Do.
I a, b, c.....	8	40	11	...do.....	Nicotine sulphate 1 part, 6 per cent kerosene emul- sion 400 parts.	Nov. 9, 1912, dormant.	Dec. 22	100	8	82	0	8	0	None....	Do.

TABLE XLIV.—Coating sprays against the terrapin scale applied in 1912.

Plat.	Ex- per- iment No.	Trees.	Age.	Degree of intesta- tion.	Formula.	Application.	Scale count.					Per cent dead in check.	Spray injury.	Final results.
							Date.	Total.	Dead.	Living.	Per cent para- sitized.	Per cent dead.		
V.....	1	90	Yr. 11	Heavy.....	Self-boiled lime sul- phur, 8-8-50.	May 24, 1912 (scales ma- ture).	Sept. 3	200	23	177	10	11.5	None.....	Inefficient.
IX.....	2	77	11	do.....	do.....	June 17, 1912 (leafward migration).	July 8	100	15	85	0	15	0 do.....	Do.
X.....	3	105	11	do.....	do.....	(June 17, 1912 July 6, 1912 July 17, 1912 July 8, 1912)	July 8 Sept. 13 July 8	100 800 100	0 761	100 39 100	0 0 0	0 96.3 0	0 do..... 0 do..... 0 do.....	Do. Do. Do.
XI.....	4	77	11	do.....	do.....	do.....	Sept. 5	100	90	10	0	90	None.....	Do.
VII d.....	5	24	11	do.....	Self-boiled lime sul- phur 8-8-50, and tobacco extract.	July 9, 1912 (leaf-at- tached lar- vae).	do.....	100	90	10	15	90	0 do.....	Do.
VII d.....	6	10	11	do.....	Self-boiled lime sul- phur 8-8-50, plus 1 gallon tobacco extract.	July 9, 1912	do.....	100	90	10	15	90	0 do.....	Do.
Southcheck a.....	7	21	11	do.....	Stone lime 12 pounds, sulphur 3 pounds, water 50 gallons.	Aug. 6, 1912 (twigward migration).	Aug. 16	100	25	75	10	25	0 do.....	Do.
III b, west end.....	8	12	11	do.....	Paris white 15 pounds, glucose 3 gallons, water 47 gallons.	Aug. 5, 1912	Sept. 30	100	10	90	10	10	0 do.....	Do.
III a, west end.....	9	12	11	do.....	Stone lime 20 pounds, casein 5 pounds, water 50 gallons.	Aug. 6, 1912	do.....	200	22	178	10	11	0 do.....	Do.
III a, east end.....	10	7	11	do.....	Pulverized China clay 15 pounds, water 50 gallons.	do.....	do.....	100	10	90	10	10	0 do.....	Do.

TABLE XLV.—Experiments against the terrapin scale with coating sprays to which flour had been added, season of 1913.

Experiment No.	Trees.	Age.	Degree of infestation.	Formula.	Application.	Scale count.						Per cent dead in check.	Spray injury.	Final results.
						Date.	Total.	Dead.	Living.	Per cent parasitized.	Per cent dead.			
1.....	12	Years, 12	Heavy.....	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds, water 50 gallons.	June 12, 1913.....	July 8	1,007	948	59	5	94.1	21	None	Very efficient.
2.....	12	12	do.....	do.....	June 12, 1913.....	July 7	1,152	1,141	11	5	99	21	do.....	} Do. Inefficient. Do. Efficient.
3.....	12	12	do.....	do.....	July 10, 1913.....	Aug. 4	100	99	1	5	99	21	do.....	
4.....	3	12	do.....	do.....	July 10, 1913.....	Oct. 14	100	26	74	5	26	21	do.....	
5.....	8	12	do.....	do.....	July 29, 1913.....	Aug. 6	100	15	85	0	15	0	do.....	
				Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds nicotine sulphate 1 pint, water 50 gallons.	June 17, 1913.....	June 28	2,306	2,093	23	5	90.71	21	do.....	
6.....	16	12	do.....	do.....	June 17, 1913.....	} Aug. 8	100	90	10	5	90	21	do.....	Do.
7.....	6	12	do.....	do.....	July 10, 1913.....		100	26	74	5	26	21	do.....	Inefficient.
8.....	1	12	do.....	do.....	July 29, 1913.....	} Aug. 6 Aug. 9	100	26	74	5	26	21	do.....	Do.
9.....	5	12	do.....	Flour 10 pounds, water 50 gallons.	July 10, 1913.....	Aug. 8	100	0	100	0	0	0	do.....	Do.
10.....	5	12	do.....	Flour 10 pounds, stone lime 15 pounds, sulphur 20 pounds, water 50 gallons.	July 10, 1913, twigward migration.	do.....	100	0	100	0	0	0	do.....	Do.

The spray used in experiment 1, which was made just before the flower buds burst, was very effective as an insecticide. Every scale that was covered with the spray solution was killed. Of 1,000 scales examined only 1.2 per cent were alive, and these were protected in various ways from the spray and were not completely drenched. The spray injury was severe, however, owing to the excessive amount of oil.

Experiment 2 was made late in the fall with 2 per cent less oil. This spray was very efficient against the scale, but the injury was more pronounced than in experiment 1. The trees used in both experiments required severe pruning and a liberal application of sodium nitrate to restore them to their original vigor.

Experiment 3 was made at Washington, D. C., to determine the effect of this oil upon young trees. A vigorous 2-year-old tree was thoroughly sprayed with a hand sprayer until all the scales were wet with a 10 per cent emulsion of the oil. All the scales upon this tree were destroyed, but the spray injury was so severe that the tree died. It is worthy of note that this was the only tree killed with oil during the two seasons' work. The increased tolerance of the older trees to oil seems to be due entirely to the protection afforded by their corky bark.

Experiment 4 was also made at Washington. It shows that cottonseed oil in a 5 per cent emulsion can be applied effectively and safely to 2-year-old trees in mild winter weather. This formula, however, does not contain enough of oil to make it effective against the terrapin scale when applied on old trees, as is clearly shown in experiment 9.

Experiment 5 was also made at Washington, D. C. Two heavily infested 2-year-old trees were sprayed with a 5 per cent emulsion of equal parts of cottonseed oil and gasoline. A hand sprayer was used and all the scales were thoroughly wetted with the spray. Nine days after the application 98 per cent of the scales were dead and no spray injury developed during the season. This spray was also effective against scale upon old peach trees, as is shown in experiment 8.

In experiment 6 the amount of oil was reduced to 1.5 per cent and the gasoline was increased to 3.5 per cent. The application was made in the same manner and at the same time as in experiments 3, 4, and 5, but it was ineffective, owing to the small percentage of oil. The high percentage of gasoline increased the wax-solvent power of the solution and its narcotic power, but did not directly contribute to its killing power.

Experiment 7, in which 10 per cent cottonseed oil and 5 per cent gasoline was used, gave practically the same results as 10 per cent cottonseed oil when used alone. Since experiment 7 shows less

spray injury than experiment 3, it is evident that the gasoline did not tend to increase the spray injury. This experiment, in connection with experiment 3, shows that a 10 per cent emulsion of the oil, even when used at the most favorable season, is too strong for 2-year-old trees whether used with or without gasoline. The formula in experiment 7, while containing more oil than is required for killing scale upon young trees, would undoubtedly be very effective when used upon old trees, but owing to the effective results obtained with $2\frac{1}{2}$ per cent of this oil in experiments 5 and 8, it was not thought advisable to experiment further with the 10 per cent emulsion.

In experiment 8 an emulsion containing $2\frac{1}{2}$ per cent of cottonseed oil and $2\frac{1}{2}$ per cent of gasoline was applied to 28 vigorous 12-year-old trees at Mont Alto, March 29, 1913, with very satisfactory results. The interval between the application of this spray and the time of making the scale count was too long to show the maximum efficiency of the spray, nevertheless the mortality as shown is above 90 per cent and there was no spray injury. Observations made upon the trees used in this experiment show that the oil content could have been considerably increased without injury to the trees.

Experiment 9, in which a 5 per cent emulsion of cottonseed oil was carefully sprayed upon 16 trees at Mont Alto, Pa., gave unsatisfactory results. The mortality was about 50 per cent and the spray injury was negligible. The oil in this case seemed to lack penetration and spreading power.

A comparison of the data in this experiment with that in experiments 5, 8, and 10 shows that a 5 per cent emulsion of this oil is satisfactory only when used with gasoline. Experiment 10 was the last one performed with cottonseed oil. An extensive spraying was made to test the efficiency of the gasoline and cottonseed-oil emulsion when applied in the fall. This experiment was successful and showed that the terrapin scale can be attacked in the fall with satisfactory results. Cottonseed oil, however, gives its best results when applied in the spring. It is possible to increase the percentage of cottonseed oil in this formula up to as high as 7 per cent without noticeable injury to the trees. This increase in oil, however, adds to the cost of the spray without greatly increasing its efficiency, except for use on old trees with very rough bark. In this case it may be found of advantage to use 7 per cent of the oil.

LINSEED OIL.

Five experiments against the terrapin scale were made with raw linseed oil. The essential facts established in these experiments are shown in Table XLI.

Experiment 1 was made at Mont Alto, Pa., upon vigorous 11-year-old trees that were nearly ready to burst into bloom. The same

power outfit was used as in applying the cottonseed-oil sprays. The oil was emulsified in the same way as kerosene in making kerosene emulsion. This oil at 20 per cent gave an efficiency of from 93 to 100 per cent, but the injury to the trees was severe. It did far less injury, however, than any other of the oils used at this strength. This experiment shows that raw linseed oil was a promising oil and that it should be used at a much decreased strength.

Experiment 2 was performed on March 19, 1913, by spraying a vigorous 2-year-old tree at Washington, D. C., with a 10 per cent emulsion of raw linseed oil. This spray was applied very thoroughly with a hand sprayer at the time the buds were swelling. Every scale upon this tree was killed and there was no spray injury. The experiment shows that it is feasible to apply a 10 per cent emulsion to 2-year-old trees in the spring without injury.

Experiment 3 demonstrated that a 5 per cent emulsion of raw linseed oil will destroy more than 80 per cent of the scales upon 12-year-old trees, provided the application is made in the spring before the buds open. In experiment 4 the formula used differs from the one used in No. 3 in that gasoline was substituted for one-half of the oil. The scale count gives nearly the same efficiency for this experiment as for the preceding one. This experiment shows clearly that gasoline increases the efficiency of the spray. Experiment 5 was made by spraying 200 moderately vigorous 12-year-old peach trees at Midvale, Pa., November 5, 1913, at which date the trees had just finished shedding their leaves. An emulsion containing 5 per cent raw linseed oil and 3 per cent gasoline was applied with a power sprayer, furnishing 175 to 200 pounds pressure, and equipped with angle nozzles having apertures of one-sixteenth inch. The efficiency upon well-sprayed branches was 100 per cent and there was no spray injury.

Experiments 4 and 5 show that an emulsion containing 5 per cent raw linseed oil and 3 per cent gasoline will effectively control the terrapin scale without injury to the trees. While experiment 5 shows that linseed oil gives good results in the fall, the author recommends that this oil be applied in the spring just before the buds open.

COST OF LINSEED OIL.

At the date of writing this paragraph linseed oil sold in Washington, D. C., for 50 cents per gallon in barrel lots, and gasoline at 13 cents per gallon. The cost of this spray, exclusive of the labor of making it, would be about 3 cents per gallon.

5 gallons raw linseed oil, at 50 cents.....	\$2. 50
3 gallons gasoline, at 13 cents.....	. 39
2 pounds laundry soap, at 5 cents.....	. 10
92 gallons water.....	
100 gallons.....	2. 99

It requires from $1\frac{1}{2}$ to $2\frac{1}{2}$ gallons of this emulsion thoroughly to spray a vigorous 12-year-old tree. The average tree of this age requires about 2 gallons, while a 2-year-old tree requires from a pint to a quart. It appears that from these figures the spray material will cost from 1 cent to 8 cents per tree.

A single application of this spray, if carefully made, will control the terrapin scale. It has been found that the best way of preparing this spray is by mixing 5 gallons of raw linseed oil and 3 gallons of gasoline and then adding 2 pounds of soap dissolved in 4 gallons of hot water. The whole is churned for 5 minutes through a spray pump, then diluted to double its volume and churned again for 1 minute, after which it should be diluted to 100 gallons, when it is ready to use.

MIXED OILS.

Two experiments were performed in 1913 with emulsions of mixed oils. These emulsions were made and applied in exactly the same way as the linseed-oil emulsions.

Table XLII shows the chief details, and the results for the mixed-oil emulsions. These experiments, when compared with experiments 3 and 4 of Table XLI, show that these mixed oils were less efficient than raw linseed oil and that there is no advantage in mixing them.

NICOTINE.

Eight experiments were made with nicotine compounds. These sprays were applied partly with a barrel sprayer and partly with a power sprayer, but the same set of disk nozzles was used in all cases. The chief details and the results of these experiments are recorded in Table XLIII.

When reference is made to nicotine sulphate, the commercial article containing 40 per cent of nicotine is intended; likewise references to tobacco extract refer to preparations containing 2.7 per cent of nicotine, or its equivalent.

Experiments 5 and 6 of Table XLIV and experiments 5, 6, 7, and 8 of Table XLV are to be considered in connection with Table XLIII. Of these 14 experiments, 5 were directed against the hibernating scales (4 of these in the spring and 1 in the fall); 5 against the leaf-attached larvæ, 2 against the females while making the twigward migration, and 2 against the young females while making their maximum growth. These experiments were all negative and showed that nicotine is ineffective against the terrapin scale.

COATING SPRAYS.

A number of experiments were performed in 1912 with coating sprays, to determine the feasibility of smothering the scale. The chief details and the results of these experiments are recorded in

Table XLIV. The first 4 experiments were made with self-boiled lime-sulphur, 8-8-50, and were applied with coarse nozzles at a pressure of 100 pounds.

In experiment 1 the application was made May 24, when 95 per cent of the overwintered scales were mature. This spraying was both extensive and thorough, but was inefficient against the mature females and failed to control the sooty molds. Experiment 2 was directed against the larvæ during the beginning of the leafward migration, but gave an efficiency of only 15 per cent and also failed to control sooty molds.

In experiment 3 two applications were made, the first at the beginning of the leafward migration and the last when 95 per cent of the larvæ were upon the leaves. Both sprayings were ineffective and the small mortality (6.3 per cent) came entirely from the first application.

In experiment 4, 3 applications were made, when the leafward migration started, when 95 per cent were upon the leaves, and just before the twigward migration. These applications were also ineffective, and the mortality was no greater than in the case of experiment 1. The fungus was partly controlled, but the fruit was coated with lime to such an extent that the general effect was injurious rather than beneficial.

In experiments 5 and 6 tobacco extract was added to the self-boiled lime-sulphur, and the applications were made when 95 per cent of the larvæ were upon the leaves. These experiments gave no better results than the preceding ones and showed that tobacco extract is inefficient, at the strength used, when applied against the larvæ when they are upon the leaves.

In experiment 7 self-boiled lime-sulphur was modified to increase the thickness of the coating, and was directed against the young females. The branches of the young twigs were coated just before the females started their twigward migration. This experiment was ineffective.

Experiment 8 was made to test the smothering properties of Paris white and glucose. The application was made with a barrel pump, just before the females started migrating to the twigs. The spray was ineffective.

In experiment 9 a thick whitewash, to which casein had been added, was applied just before the young females started the twigward migration. The limbs were heavily coated, but the scales were not killed.

In experiment 10 pulverized china clay was used. It proved to be a poor coating material and was inefficient. Considered as a whole the experiments in Table XLIV indicate that self-boiled lime-sulphur is ineffective when applied at the time of the twigward migration,

both against the scale and the sooty molds. They also indicate that the other substances tested are ineffective against the terrapin scale.

The experiments with coating sprays performed in 1912 were failures, so far as controlling the terrapin scale was concerned, but they were valuable in showing that sulphur was the active component of self-boiled lime-sulphur and that its efficiency could be improved by increasing its spreading and sticking powers. It was evident also that sulphur was ineffective against the mature females.

COATING SPRAYS WITH FLOUR ADDED.

In 1913 experiments were made to perfect a coating spray by adding a spreader and sticker to self-boiled lime-sulphur and by increasing the sulphur content. The chief details and the results of these experiments are recorded in Table XLV.

In these experiments the flour was first made into a thin batter with cold water and then cooked to form a paste. The other ingredients were combined exactly as in making self-boiled lime-sulphur, after which the flour paste was added.

In the first four experiments the same spray was used. Experiment 1 was directed against the larvæ during the leafward migration and was very successful. Experiment 2 was directed both against leafward migrants and against the larvæ upon the leaves. It shows high efficiency, which is, however, entirely due to the first spraying, as is shown by the negative results in experiment 3.

Experiments 5, 6, 7, and 8 were performed with the same formula used in the preceding experiments, except that 1 pint of 40 per cent nicotine sulphate was added. The results from these experiments show that the nicotine adds nothing to the efficiency of the spray.

Experiment 9 was made with flour paste and shows that flour acts only as a spreader and adhesive and not as a killing agent.

Experiment 10 was made with modified self-boiled lime-sulphur to which flour paste was added, and was directed against the larvæ after they were well established upon the leaves. The spray was ineffective, as were all other applications made against the leaf-attached larvæ.

From these experiments it appears that the terrapin scale can be controlled by a coating spray applied against the larvæ during the leafward migration and that these sprays are inefficient at other times. Coating sprays are more difficult to apply than the oil sprays and require a first-class sprayer with a powerful agitator and plenty of pressure. Coarse-angle nozzles should be used and the underside of the leaves should be thoroughly drenched, and the spray must be applied just before the young emerge. The time for applying this spray, which is immediately after the appearance of young under the

scales, can best be determined by displacing a number of scales daily during the early part of June. In the region of Mont Alto, Pa., the young will appear under the scales about June 12. For this coating spray use the following formula:

	Pounds.
Stone lime.....	15
Sulphur.....	20
Flour.....	10
Water to make 50 gallons.	

The lime and sulphur are combined exactly as in making self-boiled lime-sulphur. The flour is made into a thin batter with cold water and cooked to a paste. It is then added to the lime-sulphur, and the whole should then be diluted to 50 gallons, when it is ready for use. Particular care must be taken to get a batter free from lumps; if this is done, and the spray is strained through a sieve, there will be no trouble in passing it through the nozzles. This spray when properly applied will kill from 94 to 100 per cent of the larvæ. It is effective only against the leafward migrating larvæ and is useless if applied after the larvæ have attached to the leaves.

SUMMARY.

SUMMARY OF LIFE HISTORY.

The female of the terrapin scale reaches maturity about the 1st of June and gives birth to living young soon afterwards. These are retained for a period of from 1 to 3 days in the brood chamber, which is a dome-shaped cavity beneath the scale. They then emerge and migrate at once to the underside of the leaves, where they settle, mostly along the midrib and the larger veins. The first instar, which lasts about 18 days, is vegetative and the larvæ show no sexual differentiation, but during the second instar, which also lasts about 18 days, sexual differentiation is very pronounced. At the end of this instar the female is very flat and circular, while the male, which is flat and decidedly oval, is protected by a conspicuous waxy structure called the puparium. After the second instar the sexes follow entirely different lines of development.

The female remains for 1 day upon the leaves after entering the third instar, which is the final instar for this sex. During this day it secretes a thin wax scale, which protects it during the twigward migration. At the beginning of this migration the female larvæ abandon the leaves and pass to the basal part of the new growth, where they make their final attachment within the area of greatest illumination. They then commence a period of rapid growth, during the first 11 days of which they develop their mating color, which is a conspicuous red band upon the middorsal line. At the time the dorsal band is completed the male migrates to the leaves, mates, and

dies. The female after mating starts a rapid growth during which the mating colors and the larval characters are lost and during which vast quantities of honeydew are deposited. By the end of the twentieth day upon the twig the female has assumed all the adult characters. After this, growth gradually slackens until the cold of the approaching winter forces the scale into hibernation. In the spring growth is resumed. Maturity is reached early in June and the scale dies early in July, after having lived about 13 months.

The male, which makes the second molt and passes all of its remaining instars, except the last day of the imago, under the protection of the puparium, loses its mouth-parts at this time and lives during the remainder of its life upon nourishment taken in the first two instars. The third or prepupal instar lasts about 2 days and is a period of rapid metamorphosis, in which the larval organs are replaced by the adult structures. In the fourth or pupal instar, which lasts for about 8 days, the adult organs reach their full development. At the fourth and final molt the imago escapes from the pupal case, but remains for about 2 days under the puparium before emerging, when it migrates at once to the twigs, copulates, and then dies, after having lived about 49 days.

SUMMARY OF REMEDIAL MEASURES.

An endeavor was made to prevent the soot injury which is the main cause of complaint from orchardists against this scale. During the first season one series of sprayings was made to control it in the presence of the living scale, and another series was made to control it by destroying the scale. It was found impracticable to control the "soot" directly. Accordingly in the second season all sprayings were made against the scale. Seven groups of materials were tested, the first of which contained corn oil, rosin oil, and gasoline. Of these, the two former were good treatments, but were very injurious to the trees. The latter was inefficient but gave promise as a wax solvent and penetrant.

MISCIBLE OILS.

The second group contained miscible oils. Nine experiments were made with miscible oil, including 5 with miscible oil and gasoline, and 2 with miscible oil and nicotine.

In the first case it was evident that miscible oil was injurious when used in the winter at effective strengths, but that it could be used without injury if applied in the spring between the swelling and the bursting of the fruit buds. It was also evident that healthy 11-year-old trees could be sprayed for three consecutive seasons with miscible oil 1 to 18 without injury to the trees, and that the scale could be controlled by two seasons' spraying with this oil.

In the second case it was evident that combining gasoline emulsion and miscible oil added to the efficiency of the oil. The greatest efficiency was obtained when 5 parts of miscible oil were added to 3 parts of gasoline (emulsified) and 92 parts of water. In the third case it was evident that adding nicotine did not increase the efficiency of miscible oil.

COTTONSEED OIL.

The third group consisted of 10 experiments made with cottonseed oil. This was a promising oil and both its penetration and wax-solvent powers were greatly increased by the addition of gasoline. The highest efficiency was obtained by using an emulsion containing

Cottonseed oil.....	5 gallons.
Gasoline.....	3 gallons.
Soap.....	2 pounds.
Water.....	92 gallons.

combined as indicated on page 67. This oil proved nearly as effective as linseed oil.

LINSEED OIL.

The fourth group consists of 5 experiments made with raw linseed oil. It was soon evident that this oil was promising. It was very efficient when used alone as a 10 per cent emulsion, but it gave even better results when combined with gasoline. The gasoline component increases the fluidity of the oil, dissolves the protecting wax film, and tends to asphyxiate the scales. After the emulsion has penetrated to the underside of the scale this component evaporates, while the other component, after smothering the scale, becomes inert. In this respect it is superior to the oils ordinarily used against this scale. The best results are obtained by using an emulsion made up as follows:

Raw linseed oil.....	5 gallons.
Gasoline.....	3 gallons.
Laundry soap ¹	2 pounds.
Water.....	92 gallons.

When made as indicated on page 82, this emulsion applied in the spring before the buds burst will control the terrapin scale at a single application and at a cost for material of from 1 to 8 cents per tree. This was found to be the most effective treatment of any of the remedies tried against this insect.

MIXED OILS.

Group 5 contains only two experiments. They show conclusively that there is no advantage in mixing linseed and cottonseed oils.

¹ This is the minimum amount; more may be required if the soap is mild.

NICOTINE.

In group 6 the efficiency of nicotine was tested in 14 experiments. Both the commercial sulphate and the aqueous solution were tested. This substance proved inefficient in all cases.

COATING SPRAYS.

In group 7 various coating sprays were tested. Twenty experiments were made. They were intended for the control of both the sooty fungus and the terrapin scale, but were ineffective against the "soot" in all cases where the insect was not killed.

From these experiments it is evident that the period in the life history of this insect when it can be most readily controlled by a coating spray is during the leafward migration. It is also evident that sulphur is the efficient component in the coating sprays, and that the ordinary self-boiled lime-sulphur lacked the spreading and adhesive properties necessary to make it an efficient coating spray. The modified formula given under "Recommendations" (second formula, below) was accordingly devised.

RECOMMENDATIONS FOR CONTROL.

Spray in the spring before the buds burst, with the following emulsion (see page 82):

Raw linseed oil.....	5 gallons.
Gasoline.....	3 gallons.
Soap.....	2 pounds.
Water.....	92 gallons.

If the foregoing formula is not used, spray with proprietary miscible oils, containing not less than 75 per cent mineral oil, at the rate of 1 part to 16 to 20 parts of water. Applications of this formula should likewise be made in the spring during the period between the swelling and the opening of the buds. (See pp. 68-73.)

To protect a crop after the trees are in foliage, spray just before the leafward migration (see pp. 19-24) with the following formula (p. 85):

Flour (in paste).....	10 pounds.
Stone lime.....	15 pounds.
Sulphur.....	20 pounds.
Water to make.....	50 gallons.

This should be applied at the time the young appear in the brood chambers, but before they have emerged. This time can be best determined by making a daily examination of infested twigs. Since the young are not destroyed after they have attached, only one thorough application is advisable. This treatment, owing to the limited time for its application, is not as practicable as the dormant sprayings and should be used only in emergencies. This spray does not seriously coat the fruit.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 352

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.



Washington, D. C.

PROFESSIONAL PAPER.

May 5, 1916

THE CHERRY LEAF-BEETLE,¹ A PERIODICALLY
IMPORTANT ENEMY OF CHERRIES.

By R. A. CUSHMAN, *Entomological Assistant*, and DWIGHT ISELY, *Scientific Assistant*,
Deciduous Fruit Insect Investigations.

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INTRODUCTION.

The sudden appearance of enormous numbers of a small red beetle throughout a wide area in the northeastern United States in the spring of 1915 caused consternation among many of the fruit growers of that region. It attacked the foliage of cherry and peach trees and to some extent the fruit of the former. Its range of greatest destructiveness was in New York, Pennsylvania, and northern West Virginia. This insect is the so-called cherry leaf-beetle (*Galerucella cavicollis* LeC.) (fig. 1), a member of the family Chrysomelidæ, and is closely allied to the imported elm leaf-beetle (*G. luteola* Müller): At the time of its appearance practically nothing was known by fruit growers in regard either to its habits or its control, and comparatively little was known by entomologists. Sporadic outbreaks had occurred in the past, but references to them in entomological literature are brief. Taking advantage of this unusual outbreak, the writers have undertaken to secure as complete data as possible in regard to its natural food plants, its immature stages and

¹ *Galerucella cavicollis* LeConte; order Coleoptera, family Chrysomelidæ.

NOTE.—While this paper was going through the press an account of this insect appeared in the Journal of Agricultural Research under the authorship of Glenn W. Herrick and Robert Matheson of Cornell University.

life history, and the means for its control. The work herein discussed was conducted at North East, Pa., during the season of 1915.

FOOD PLANTS.

In the region covered by the writers' observations the natural food plant of this insect is the pin, fire, or bird cherry (*Prunus pennsylvanica*). (Pl. I; Pl. V, *A* and *B*.) Wild black cherry (*P. serotina*) and chokecherry (*P. virginiana*) are entirely immune from attack, even by the beetles. Among cultivated fruits only sour cherry and peach trees are attacked. Even in the sour cherries those varieties, such as the Early Richmond, which have comparatively thin foliage, are much more seriously injured than the thicker leafed varieties. Sweet cherry and plum, common report to the contrary notwithstanding, are not at all eaten. The beetles have frequently been found on these trees, but never feeding. Color is lent to the belief that they attack plums by the very general prevalence of the shot-hole fungus on these trees, casual observers taking the holes caused by the fungus to be the feeding marks of the beetles.



FIG. 1.—Cherry leaf-beetle (*Galerucella cavicollis*): Adult beetle. Much enlarged; natural size at right. (Original.)

All of the foregoing observations in relation to cultivated trees apply to the adult beetle. On only one occasion were larvæ found on anything other than the pin cherry. On August 24 two larvæ were found on leaves of Early Richmond cherry. One of these had attained nearly full growth, while the other was still in the first stage. Neither of them lived to maturity. In the confinement of cages larvæ of the second and third stages fed sparingly on leaves of cultivated cherry, but first-stage larvæ died without feeding. One lot of 57 newly hatched larvæ were fed on peach leaves, but within 6 days all were dead.

From the records just given it appears that, except in the adult stage, this species is not likely ever to become of economic importance.

The beetles are mentioned in literature as having been taken on various other plants, such as apple and chestnut, but these were probably merely strays, although Davis (1896)¹ states definitely that they attacked apple in Michigan. The apple was, however, entirely immune to attack during the present outbreak.

Lugger (1899) mentioned "native plum" as a natural food plant as well as the "fire cherry."

The old idea that *G. rufosanguinea* Say is a Southern form of *cavicollis* together with an obvious mixing of data has led to the inclusion, in literature, of *Ranunculus acris*, a buttercup, among the host plants of *cavicollis*. *G. rufosanguinea* is known to breed on wild azalea.

¹ Dates in parentheses refer to the Bibliography, p. 25.

In a note entitled "Beetles on buttercup and azalea," in answer to a correspondent, Walsh (Pract. Ent., 1866, vol. 2, p. 9) determined *G. rufosanguinea* from *Ranunculus acris* and another beetle from *Azalea nudiflora*. Quite obviously the *G. rufosanguinea* should have been recorded from the azalea. Lintner (1896), quoting Walsh, says: "If the identification of Walsh was correct, it [i. e., *G. cavicollis*] has also been taken in June on buttercup, *Ranunculus acris*, in the vicinity of Albany, N. Y."

DISTRIBUTION.

Galerucella cavicollis is known to occur from Canada and the New England States west to Minnesota, and south along the Appalachians into West Virginia and Virginia. The type specimen is said to have come from North Carolina. It has been taken, according to Smith (1909), at Sea Isle and Anglesea, both localities near the southern point of New Jersey. According to Chittenden (1899), it has also been taken at Vancouver, British Columbia, and in Texas. It quite likely occurs throughout the natural range of its native host plant, *Prunus pennsylvanica*, which, according to Gray,¹ is "Lab. to B. C., S. to Pa., Great L. region, centr. Ia., and along mts. to N. C., Tenn., and Colo." Britton and Brown² add Georgia.

ECONOMIC HISTORY PREVIOUS TO 1915.

Economic injury by this beetle was first recorded in 1894 by Davis, who found it feeding on cultivated cherry at Bellaire, Mich. It was again reported the following year from Au Sable Forks, N. Y., by Lintner. In 1897 it was reported as destructive at Traverse City, Mich., by Pettit, and (1898) at Corning, N. Y., by Felt. The next year Chittenden (1899) recorded injury from St. Ignace, Mich., and Spruce Creek and Lebanon, Pa. Injury was observed by Harvey (1901) at Orono, Me., in 1900.

No outbreaks occurring after this time have been specifically recorded in entomological literature, although there are some general references to the beetle. However, economic injury was reported by correspondents to the Bureau of Entomology in 1912 from Newberry and Pontiac, Mich., and in 1914 from Muncy and Williamsport, Pa.

THE 1915 OUTBREAK.

EXTENT OF INJURY.

The 1915 outbreak was probably by far the most injurious that has ever occurred. Complaints regarding this pest were much more numerous and from many more localities than those from all preceding years combined. The beetle, instead of inflicting injury in a few

¹ New Manual of Botany (7th edition).

² Illustrated Flora of the United States and Canada.

restricted localities, was generally destructive throughout two comparatively large regions; the one, in the Appalachian region, involving the greater part of New York, Pennsylvania, and northern West Virginia; the other in the northern part of lower Michigan, especially in the Grand Traverse region, where cherry growing is very extensive. In regard to the latter region Prof. R. H. Pettit, of the Michigan Agricultural College, writes (in litt.) that during the period of destructiveness by this beetle nearly every mail brought complaints. No complaints were received by the Bureau of Entomology from the territory intervening between these two regions. One of the writers, on June 17 and 18, traveled by trolley through Ohio from Sandusky to Ashtabula, stopping at a number of points between, and no injury by these beetles was noted.

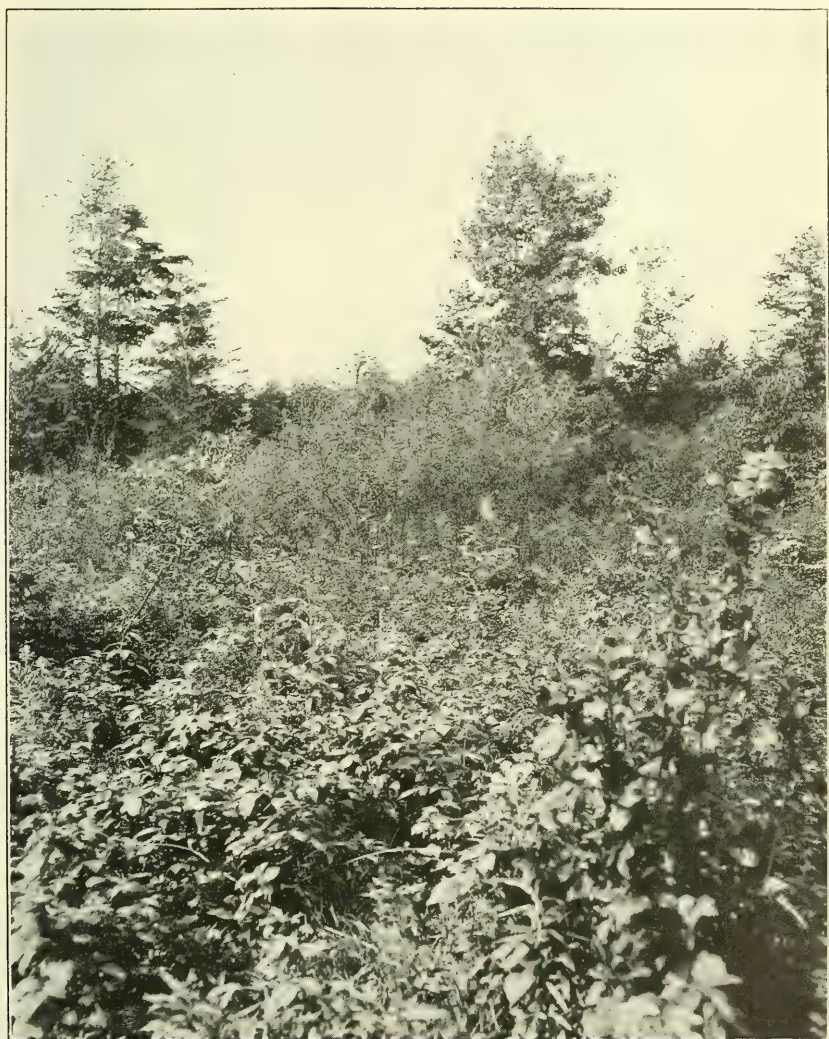
The majority of complaints came in June. However, the beetle was reported from Jamestown, N. Y., as early as May 12, and from Williamsport, Pa., May 21. The general migration to cultivated food plants in northwestern New York and Pennsylvania did not occur until the week of June 7. Farther south, in West Virginia, it occurred about the same time, the first report having been sent June 9.

THE 1915 INVASION OF THE LAKE ERIE GRAPE BELT.

The beetles appeared in the vicinity of North East, Pa., on June 7, literally covering the leaves of the trees attacked. Early in the morning their advent attracted the attention of fruit growers living 3 or 4 miles south of Lake Erie, and by noon they were found in great numbers in orchards near the lake. After this first day of migration the increase was comparatively small, and no increase at all was noticeable in the vicinity at large after June 9, although there was some local shifting of numbers.

During the first few days of the migration stories told by fishermen of the abundance of the beetle on the lake were current; how pieces of wood floating on the water had been covered with them; how they had crowded on black buoys until the color of the buoys had been changed to red; and how the water itself had been full of them. But even after giving these stories the full discount that is generally accorded to stories of like origin, the fact still remains that the migration of great numbers of beetles extended for some distance over the lake. Dead beetles were found in considerable numbers on two of the lake beaches by one of the writers on June 10, when a strong north wind was blowing, and it was reported that they had been washed up in windrows. The occurrence of these beetles in the lake gave rise to the opinion that they had come from Canada.

The actual source of the beetles was to the south of the grape belt, from cut-over forest land grown over by pin cherry. The preceding



TYPICAL BREEDING GROUND OF THE CHERRY LEAF-BEETLE (*GALERUCELLA CAVICOLLIS*).
A group of pin-cherry bushes stands in the center of the picture. (Original.)



FIG. 1.—COMPARATIVE INJURY TO LOWER AND UPPER BRANCHES. (ORIGINAL.)



FIG. 2.—A YOUNG ORCHARD DEFOLIATED. (ORIGINAL.)

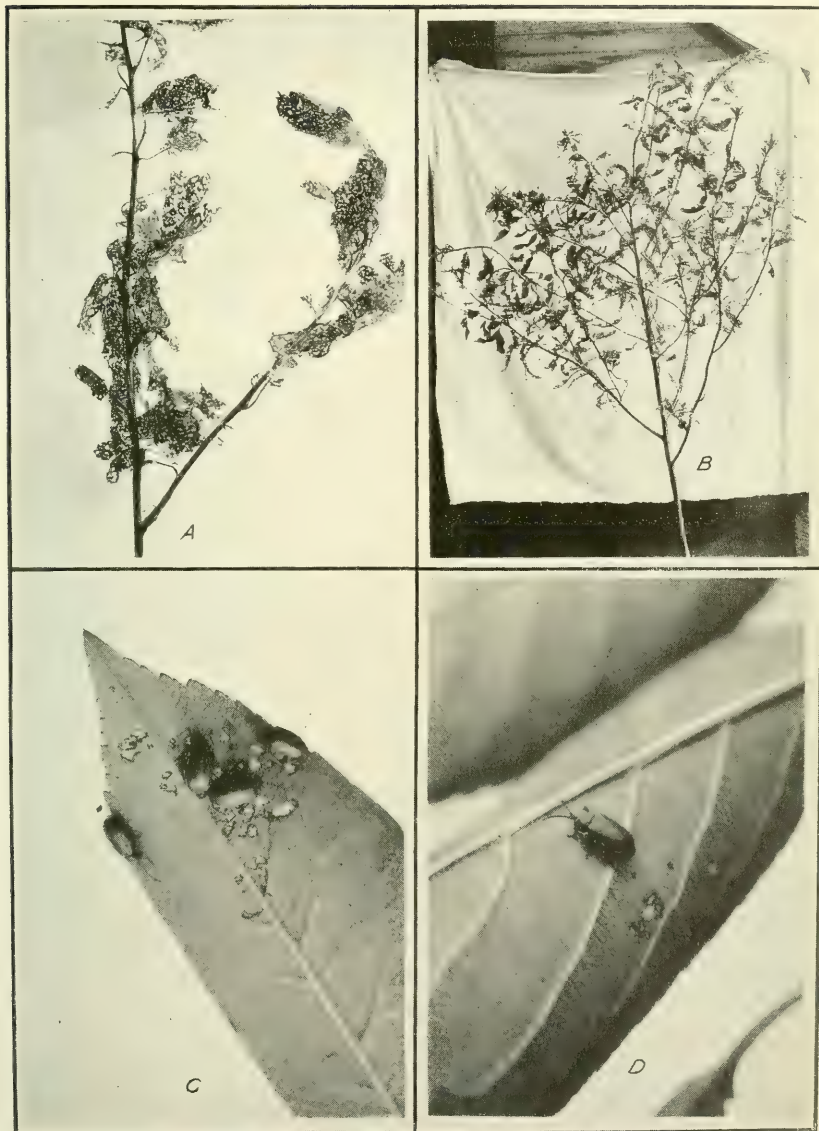
DEFOLIATION BY THE CHERRY LEAF-BEETLE OF YOUNG RICHMOND CHERRY TREES.



INJURY TO FOLIAGE AND FRUIT OF CHERRY BY THE CHERRY LEAF-BEETLE. (ORIGINAL.)



INJURY TO FOLIAGE AND FRUIT OF CHERRY BY THE CHERRY LEAF-BEETLE. (ORIGINAL.)



THE CHERRY LEAF-BEETLE.

Figures *A* and *B* show the effect of feeding of the cherry leaf-beetle on pin cherry. Figures *C* and *D* show beetles feeding on leaves of cultivated cherry. (Original.)

season had undoubtedly been favorable to the development of unusual numbers of these beetles—as much as their native host plant could support. Furthermore, the foliage of the pin cherry was reduced by a freeze on May 27, and perhaps in a part of the range by tent caterpillars also. Similar conditions were probably responsible for the outbreak in Michigan. These conditions induced a migration which was given direction by a strong wind that blew from the south-east and south on June 5, 6, and 7. It is probable that the majority of the beetles had emerged from hibernation and had been feeding for some time before their advent in the grape belt, for an outbreak was reported from Jamestown, N. Y., about 25 miles south of Lake Erie, as early as May 12.

Within a few days after their arrival the numbers of the beetles began to decrease in some orchards, and in two weeks this was general. By the latter part of June practically all had disappeared from the orchards, although a few scattering ones were found as late as early August.

CAUSE OF INCREASE OF BEETLES.

The increased numbers of the cherry leaf-beetle may be attributed to an increase in abundance of its natural food plant, the pin cherry. This tree springs up rapidly along roadsides and in cut-over or fire-swept forest land which has been left uncultivated. Such lands cover wide areas in western Pennsylvania, and furnish ideal breeding conditions for the beetle. A typical view of such a situation is shown in Plate I.

FEEDING HABITS AND DESTRUCTIVENESS.

The adult cherry leaf-beetle feeds almost exclusively on the under-side of the leaves of the plants attacked (Pl. V, *C*, *D*), eating small, irregular holes through the lower epidermis and parenchyma and sometimes through the entire leaf. These holes may join one another or come so close together as to skeletonize the leaf. In a few days after feeding, the upper epidermis thus exposed dries and falls out, and, in case of severe injury, the whole leaf dries, and defoliation ensues. To an extent it feeds also upon the fruit of the cherry, scarring and pitting it. (Pls. III, IV.)

On cold days and at night the beetles crowd on the upper surface of the leaves, and hence have given the impression that they feed there. Occasionally the writers have found beetles feeding on the upper surface of peach leaves, usually those attacked by leaf curl, and once on the upper surface of cherry leaves. The misapprehension in regard to their feeding on plum has been discussed in an earlier paragraph. The shot-hole fungus, responsible for this mistaken belief, also attacks other stone fruits which the beetle attacks, and

caused the impression that the injury by the beetle was greater than really was the case.

The larvæ of all ages feed in a manner similar to the adults, on the under surface, eating through the leaf to the upper epidermis, but leaving that intact. Occasionally a first-stage larva is found feeding on the upper surface, but this occurs only on very young leaves that have not entirely unfolded.

The feeding preference for sickly or injured trees was marked. Such trees were invariably loaded with beetles, while the surrounding trees may have been comparatively free from attack. The foliage on an unhealthy branch was attacked before the rest of the tree. The preference for the foliage on the lower limbs to that of the upper was still more conspicuous, for the lower limbs may have been completely defoliated, while the foliage of the upper limbs was comparatively uninjured. (Pl. II.)

The period of economic injury due to this beetle extended over 14 or 18 days after its first appearance in June. Probably the greater part of the feeding was done during the first three or four days. There was no injury noticeable from the later brood.

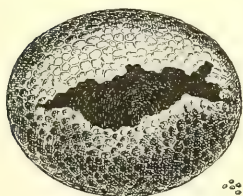


FIG. 2.—The cherry leaf-beetle: Egg. Much enlarged. (Original.)

Severe injury due to this beetle was confined almost entirely to the Early Richmond cherry, especially to young trees. (Pl. II.) In a few young orchards, within four days after the first appearance of the beetles, the foliage on the lower half of the trees was a withered brown, as if it had been burned. In two weeks the trees were almost completely defoliated. On peach and other varieties of cherry trees, although in some instances the feeding appeared quite severe, there was little defoliation.

DESCRIPTION OF STAGES.

THE EGG.

The egg (fig. 2) was first described by Chittenden (1899). It is nearly spherical and bright reddish brown and has the surface deeply pitted with irregularly hexagonal areas. The eggs vary somewhat in size and proportions, but average about 0.75 mm. long by 0.65 mm. in width.

THE LARVA.

Except for the increase in size, all three larval instars are very similar. In the early part of each instar the larva is nearly uniform, very dark olive in color, about three times as long as broad, and with short stout legs. It is broadest at the prothorax, which is about twice as broad as the nearly hemispherical head, and tapers backward to the ninth abdominal segment, which is slightly narrower than the head. Each of the three thoracic and the first eight abdominal segments are more or less conically produced at the sides and bear long bristles extending laterally. Dorsally there are transverse rows of short bristles across the front of the prothorax and double rows across each of

the other thoracic segments, and all abdominal segments except the ninth and tenth. The head is provided with a few scattered long bristles. The ninth abdominal segment is rounded behind and concave above, very heavily chitinized, and with a row of long bristles around the edge. Below it is rather conical, with the very small tenth segment forming the apex of the cone. The latter bears the anus, which is modified to form an auxiliary organ of locomotion. On each side, between the prothoracic and mesothoracic segments, can be seen a small tubercle surrounding the mesothoracic spiracle, and each of the first eight abdominal segments is provided with a pair of spiracles. On each side of the middle the prothorax is irregularly impressed. This concavity persists through all stages.

At full growth (fig. 4) each instar is very much distended, the yellowish skin becomes visible, and the dark color is confined to plates and patches, the head, and the legs. The abdomen is parallel sided and wider than the thorax. The head and ninth abdominal segment, at least above, do not share in this distension, but retain the size originally assumed after the molt. The dorsal surface of the prothorax is covered by a single large, dark-colored plate, flanked on either side by the dark colored, chitinized tips of the lateral prominences. Just below the latter are two small plates partially surrounding the base of the coxa. Ventrally the dark

color is confined to a nearly square median patch with a very small oval patch behind it. In the mesothoracic and metathoracic segments the dorsal plate is broken up into two double transverse rows of three plates each, the middle one in each row being much the largest, and transversely elongate. The lateral edges of the dorsum are very heavily chitinized and dark colored. Below the latter are two smaller plates, the anterior one of which on the mesothorax bears the spiracle, the other being the tip of the lateral prominence. Each of the coxæ is partially surrounded above by two small plates as in the prothorax. Ventrally there are three plates, a large transverse anterior one and a pair of small, nearly oval ones posteriorly. The dorsal plate of each of the first eight abdominal segments is similar to that of the mesothorax and of the metathorax, being broken up into two double rows of plates, but on the lateral edge of the dorsum are two very small plates, the posterior one of which bears the spiracle. Beyond these is the chitinized apex of the lateral prominence. Below the color is distributed in a transverse row of five spots. The ninth segment has ventrally a crescent-shaped plate in front of and partially surrounding the very small tenth segment, which bears the anus. The tenth segment is heavily chitinized laterally and posteriorly. (Fig. 5.)

The newly hatched larva is shown in figure 3. The comparative size of the three larval stages is indicated by figure 6, which shows the heads and ninth abdominal segments drawn to the same scale.

First instar.—The first larval instar (fig. 3) varies with age from 2 to 3 mm. in length with the head 0.38 mm. and the ninth segment 0.36 mm. broad. (Fig. 6, a.)



FIG. 3.—The cherry leaf-beetle: Newly hatched larva. Much enlarged. (Original.)

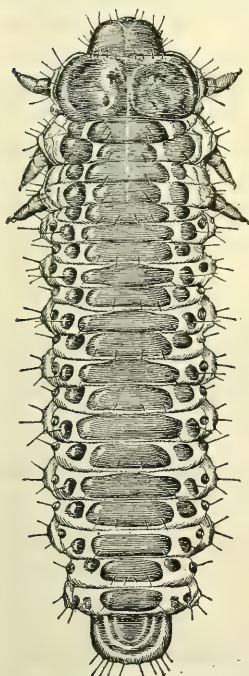


FIG. 4.—The cherry leaf-beetle: Full grown larva. Much enlarged. (Original.)

Second instar.—Immediately after the first molt the second instar is about 3 mm. long, and at full growth 4.5 mm. long. The head is 0.57 mm. and the ninth abdominal segment 0.5 mm. broad. (Fig 6, b.)

Third instar.—The newly molted larva of the third instar is 4.5 mm. long with the head 0.78 mm. and the ninth segment 0.7 mm. broad. At full growth (fig. 4) it is 7 mm. long and the measurements of head and caudal segment are unchanged. (Fig. 6, c.)

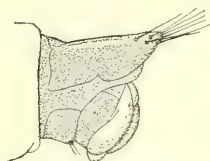


FIG. 5.—The cherry leaf-beetle: Eighth and ninth abdominal segments, lateral view, showing extruded end of alimentary canal used as auxiliary organ of locomotion. Much enlarged. (Original.)

THE PUPA.

The pupa (fig. 7) is slightly less than 5 mm. long, bright yellow, and with a pair of strong curved spines at the apex of the abdomen. The prothorax has the concavity characteristic of all stages of the species. The head has a curved row of four bristles above, the concave side of the curve to the front. On the pronotum are two rows of four bristles each, the anterior one curved to the front and the posterior one to the rear, and in addition a long bristle on each lateral angle and two near the posterior edge. The scutellum and metanotum each have a nearly straight row of four bristles.

Each of the abdominal segments, except the last, has a pair of small bristles near the middle, and a single long bristle at each lateral angle. Each femur has a pair of apical bristles. The spiracles of the first five abdominal segments and of the mesothorax are conspicuous from their black color; the outer ends

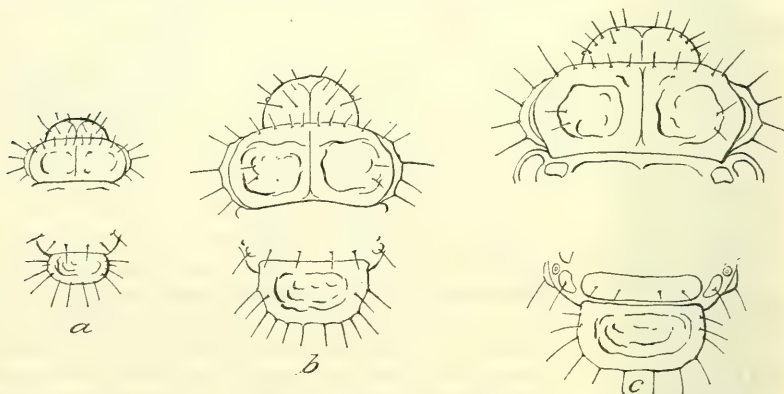


FIG. 6.—The cherry leaf-beetle: Larval heads and caudal segments, showing proportional size in the three instars: a, First instar; b, second instar; c, third instar. Greatly enlarged. (Original.)

of the tracheæ show black through the body wall for a short distance. The spiracles of the sixth and seventh segments are paler.

THE ADULT.

The adult beetle is rather oval in shape, about one-sixth of an inch long by about one-half as broad, and somewhat flattened. It is dull red with black legs and antennæ.

As Le Conte's original description of the species is in Latin, the description given by Horn (1893) is quoted below:

G. cavicollis Lec., Proc. Acad. 1865, p. 216. Oval, narrower in front, subdepressed; color dull red, slightly shining, very sparsely finely pubescent. Antennæ entirely

black. Head red, coarsely punctured, without median depression, frontal tubercles smooth. Thorax nearly twice as wide as long, narrower in front, sides arcuate, or obtusely subangulate, hind angles distinct, base on each side obliquely sinuate, disc feebly convex, a broad depression each side and another along the middle, surface coarsely punctured, more densely in the depressions; scutellum red; elytra broader behind the middle, sides arcuate, margin explanate, humeri distinct, but rounded; sutural angle well marked, but obtuse; disc with coarse and deep punctures not crowded, less deep near the apex, interspaces smooth, shining. Body beneath red, the metasternum often piceous, sparsely finely punctate and finely pubescent. Legs variable in color entirely red to almost entirely piceous. Length .18-.22 inch; 4.5-5.5 mm.

Male.—Claws finely bifid at apex. Last ventral segment broadly emarginate at apex, with a deep triangular depression limited by a sharply elevated line.

Female.—Claws more deeply bifid, the parts more divergent. Last ventral segment with a very slight emargination, in front of which is a slight fovea.

The middle coxæ are absolutely contiguous, the mesosternum is not prolonged between them, except as to the color of the legs no variation has been observed in this species.

LIFE HISTORY.

In the life-history work data were obtained on nearly 600 individuals, almost half of which were carried through their entire development from hatching to emergence of the adult insect. Daily observations were made and recorded, so that all transformations were noted within 24 hours of their occurrence.

It should be noted that the period—August and the first half of September—covered by these observations was one of unusually low temperature and high humidity for the season. In August there was at Erie, 16 miles west of North East, an average daily deficiency in temperature of 2.3° F. and an excess in precipitation over the normal, for the month, of 6.02 inches. In September the temperature was higher, but the precipitation was still abnormally high. The life-history periods shown by this data, therefore, are probably somewhat longer than the normal for the species.

The life-history work was carried on in 1-inch vials, the larvæ being supplied daily with fresh leaves of pin cherry. For pupation about $1\frac{1}{2}$ inches of earth was supplied. For larger lots jelly tumblers were used. Very few of the individuals failed to mature and emerge as beetles.

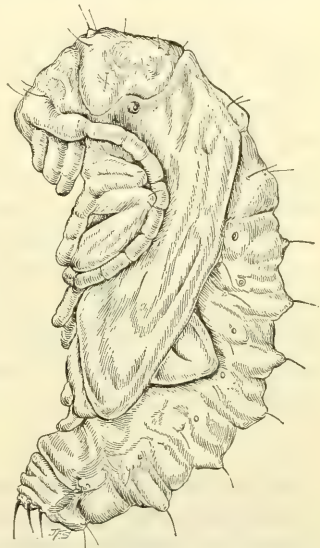


FIG. 7.—The cherry leaf-beetle: Pupa. Much enlarged. (Original.)

THE ADULT BEETLE.

Reaching the adult stage in the late summer and early fall, the beetles feed for a few weeks, and then seek out a protected situation in which they pass the winter. According to Pettit (1904) the beetles pass the winter several inches below the surface of the ground. Emerging from hibernation in the spring, they feed again for some time, mate, and the females descend to the base of the trees, where, among the decaying leaves and other vegetable matter, they deposit their eggs. Occasionally they utilize for this purpose accumulations of rubbish in the cavities in the bark of large trees. In such situations eggs have been found as high as 4 feet above the ground.

INCUBATION PERIOD.

No definite data on the incubation period were obtained, but on August 3 and 5 two lots of eggs were collected and placed in vials with the rubbish on which they were deposited. Most of those of August 3 had already hatched, but young larvæ continued to emerge until August 14, 11 days after the collection of the eggs. This lot was collected on the hills about 4 miles back from the lake. The lot of August 5 was collected only about a mile from the lake, and included a much smaller percentage of hatched eggs. This lot continued to produce larvæ until August 18, 13 days after collection. These figures are probably very near to the incubation period for the season of 1915, since Chittenden (1899) records a period of 11 days in 1898 at Washington, D. C.

THE LARVA.

In hatching the larva cuts an irregular slit in one side of the egg. It then ascends the tree, and, feeding on the underside of the leaf, grows very rapidly. During its feeding period it molts twice. In molting the skin splits down the middle line of the thorax, the split extending on to the head, where it divides and extends to each side of the mouth. The head, thorax, and appendages are withdrawn, and the larva secures a hold on the leaf with its feet and crawls out of its old skin, which remains for some time fastened to the leaf.

First instar.—In the course of the life-history work 243 larvæ were carried through the first instar. Of these 79 required 4 days; 140, 5 days; 17, 6 days; 5, 7 days; 1, 10 days; and 1, 11 days. This gives an average period for the first instar of 4.83 days. The first of these hatched on August 5 and the last molted for the first time on August 24, this being the period in which all the data on this instar were obtained. Table I summarizes these data.

TABLE I.—*Period of first larval instar of the cherry leaf-beetle at North East, Pa., 1915.*

Number of individuals.	Duration of first larval instar.
	<i>Days.</i>
79	4
140	5
17	6
5	7
1	10
1	11
243	14.83

¹ Average.

Second instar.—Data for the duration of the second instar were obtained from observations on 268 larvæ. The period covered by these observations was from August 6, when the earliest first molt took place, to August 29, when the last one molted for the second time. Table II shows the results obtained:

TABLE II.—*Period of second larval instar of the cherry leaf-beetle at North East, Pa., 1915.*

Number of individuals.	Duration of second larval instar.
	<i>Days.</i>
145	3
100	4
18	5
5	6
1	7
269	13.58

¹ Average.

Third instar.—When the larva becomes full grown it leaves the tree, burrows into the soil for a fraction of an inch, and constructs its pupal cell. That portion of its life between its second molt and its entrance into the ground—that is, the feeding period of this instar—was determined for 349 larvæ, with the results given in Table III. The first of these to molt for the second time did so on August 7, and the last one entered the ground on September 5.

TABLE III.—*Feeding period of third larval instar of the cherry leaf-beetle, North East, Pa., 1915.*

Number of individuals.	Feeding period of third larval instar.
	<i>Days.</i>
64	3
211	4
55	5
8	6
8	7
3	8
349	14.12

¹ Average.

Total feeding period.—A total of 227 larvæ were carried through the entire feeding period from hatching to entrance into the ground. Table IV contains the data obtained. These data were obtained during the period from August 5, when the first one hatched, to September 5, when the last one entered the ground.

TABLE IV.—*Total feeding period of larvæ of the cherry leaf-beetle, North East, Pa., 1915.*

Number of individuals.	Total feeding period.	Number of individuals.	Total feeding period.
	<i>Days.</i>		<i>Days.</i>
3	10	1	16
49	11	2	17
115	12	5	18
36	13	2	20
7	14		
7	15		
		227	12.33

¹ Average.

PERIOD IN GROUND.

The pupal cell is nearly spherical and about 5 mm. in diameter. It is from a fourth to a half inch below the surface. Within it the insect passes through the transformations from larva to pupa and from pupa to adult. The larva lies for several days curled up as shown in figure 8 before transforming to the pupa.



FIG. 8.—The cherry leaf-beetle: Prepupal larva. (Original.)

Data on the dates of transformation of the larva are difficult to obtain, since this necessarily involves the breaking up of the pupal cell, and such data as were obtained are based on but few individuals.

Prepupal period.—In a lot of larvæ that entered the ground on August 5 daily examination showed that the first one pupated on August 13, or 8 days later. On the same day 1 pupa was found among larvæ that entered the ground on August 6, giving a prepupal period of 7 days. One out of 3 larvæ that entered the ground on August 7 had pupated 7 days later, on August 14. Larvæ that entered the ground on September 4 and 5, when the weather was much warmer than in August, required only 5 days to pupate.

Pupal period.—In the August lots just mentioned the first transformation to the adult stage took place 9 days after the first pupation, while in the September lots the pupal period was only 7 or 8 days. In a lot which entered the ground on August 22 the first one pupated on September 10, 19 days later. Unfortunately, the prepupal period for these was not determined, but as that period was passed during the very cold days of late August, it was undoubtedly longer than in the earlier and later lots, and the pupal period was probably close to 11 days in length.

Emergence of the adults takes place from a day to several days after transformation.

Total period in ground.—Five hundred and sixty-three individuals were carried through this period of their development, the time required varying from 14 to 28 days, with the greatest emergence on the twenty-second day. Table V gives the data on this point.

TABLE V.—*Total period spent in the ground by stages of the cherry leaf-beetle.*

Number of individuals.	Period in ground.	Number of individuals.	Period in ground.
	<i>Days.</i>		<i>Days.</i>
2	14	116	23
1	15	47	24
1	16	62	25
1	17	30	26
9	18	3	27
44	19	1	28
30	20		
68	21	563	¹ 22.36
148	22		

¹ Average.

The males required on the average 0.1 of a day longer than the females, the average for the males being 22.41 days and for the females 22.31 days.

DEVELOPMENTAL PERIOD.

The total developmental period, exclusive of the incubation period, of 218 individuals was obtained. This varied from 31 to 40 days, with the heaviest emergence on the thirty-third and thirty-fourth days. Table VI gives the data obtained.

TABLE VI.—*Total developmental period of the cherry leaf-beetle, exclusive of the incubation period, North East, Pa., 1915.*

Number of individuals.	Developmental period.	Number of individuals.	Developmental period.
	<i>Days.</i>		<i>Days.</i>
3	31	2	37
27	32	1	39
67	33	1	40
63	34		
45	35	218	¹ 33.76
9	36		

¹ Average

The males required 33.81 days and the females 33.73 days. Allowing an incubation period of 11 days the total developmental period would be in the neighborhood of 45 days. Table VII gives in more detail all the life-history data obtained.

TABLE VII.—*Developmental period of the cherry leaf-beetle exclusive of the incubation period, North East, Pa., 1915.*

Lot No.	Date hatched.	Date first molt.	Number of individuals.	First stage duration.	Date second molt.	Number of individuals.	Second stage duration.	Date in ground.	Number of individuals.	Feeding period, third stage.	Total feeding period.	Date adults emerged.	Number of—		Period in ground.	Period from hatching to emergence of adults.
													Male.	Female.		
				Days.			Days.	Aug. 5		Days.	Days.	Aug. 23			Days.	Days.
2												Aug. 24	3	6	18	19
												Aug. 25	2	1	19	20
6								Aug. 6				Aug. 26	2	1	23	24
												Aug. 27	2	1	18	19
												Aug. 28	2	1	19	20
												Aug. 29	3	4	20	21
												Aug. 30	6	8	21	22
												Aug. 31	4	4	22	23
9								Aug. 7				Sept. 1	1	1	24	25
												Sept. 2	7	2	23	24
												Sept. 3	5	4	24	25
												Sept. 4	4	8	25	26
												Sept. 5	1	3	26	27
11								Aug. 8				Aug. 26	1	1	28	29
												Aug. 27	2	1	18	19
												Aug. 28	2	1	20	21
												Aug. 29	1	1	22	23
												Aug. 30	2	1	23	24
												Aug. 31	2	1	24	25
												Sept. 1	3	1	25	26
												Sept. 2	19	12	26	27
17								Aug. 9				Sept. 3	6	11	20	21
												Sept. 4	1	1	20	21
												Aug. 30	1	2	22	23
												Aug. 31	2	1	23	24
												Sept. 1	2	11	24	25
												Sept. 2	12	10	25	26
												Sept. 3	4	1	26	27
8								Aug. 11	23	4		Sept. 4	2	2	22	23
												Sept. 5	1	7	23	24
												Sept. 6	3	3	24	25
								Aug. 12	3	5		Sept. 7	1	1	20	21
								Aug. 13	1	6		Sept. 8	1	1	23	24
								Aug. 14	1	7		Sept. 9	1	1	21	22

12	Aug. 11	6	3	Sept. 2	1	23
	Aug. 12	24	4	Sept. 3	1	23
	Aug. 13	11	15	Sept. 4	1	24
	Aug. 14	4	6	Sept. 5	2	23
16	Aug. 13	6	4	Sept. 6	2	23
	Aug. 14	5	5	Sept. 7	1	23
	Aug. 16	5	7	Sept. 8	1	23
3	Aug. 14	1	4	Sept. 9	1	21
4	Aug. 15	1	5	Sept. 10	2	23
7	Aug. 14	1	3	Sept. 11	1	24
	Aug. 15	3	4	Sept. 12	1	22
	Aug. 16	5	4	Sept. 13	2	22
	Aug. 17	2	3	Sept. 14	1	23
13	Aug. 15	2	3	Sept. 15	1	23
	Aug. 16	5	4	Sept. 16	2	23
	Aug. 17	1	5	Sept. 17	1	24
15	Aug. 18	1	5	Sept. 18	1	22
	Aug. 19	1	3	Sept. 19	1	23
	Aug. 20	2	4	Sept. 20	1	23
	Aug. 21	2	6	Sept. 21	1	23
	Aug. 22	1	3	Sept. 22	1	23
	Aug. 23	3	4	Sept. 23	1	23
5	Aug. 24	16	3	Sept. 24	2	33
	Aug. 25	12	4	Sept. 25	2	33
	Aug. 26	4	4	Sept. 26	1	34
	Aug. 27	12	4	Sept. 27	4	35
	Aug. 28	2	3	Sept. 28	1	36
	Aug. 29	3	4	Sept. 29	2	34
	Aug. 30	3	4	Sept. 30	1	34
	Aug. 31	3	3	Sept. 31	1	35
	Aug. 32	4	4	Sept. 32	2	35
	Aug. 33	4	4	Sept. 33	2	35

¹ Not carried further.

TABLE VII.—Developmental period of the cherry leaf-beetle exclusive of the incubation period, North East, Pa., 1915—Continued.

[illegible]

19	Aug. 12	17	4	5	Aug. 19	4	3	Aug. 21	2	5	13	Sept. 14	1	1	21	33
	Aug. 16				Aug. 24			Aug. 24	4	5	13	Sept. 13		2	20	33
20				4	Aug. 19	5	3	Aug. 23	5	4	11	Sept. 14	1	1	21	34
					Aug. 20			Aug. 24	10	4	12	Sept. 13	2	1	21	31
					Aug. 20	11	4	Aug. 24	4	4	12	Sept. 14	2	3	21	32
		Aug. 17	10					3	Aug. 24	4	4	12	Sept. 15	2	22	34
21					Aug. 21	4	4	Aug. 25	4	4	13	Sept. 14	1	1	21	33
					Aug. 21	4	4	Aug. 25	4	4	13	Sept. 15	2	1	22	34
					Aug. 24	1	5	Aug. 29	1	5	17	Sept. 16	1	1	20	35
	Aug. 13		12		4	10	4	Aug. 25	10	4	12	Sept. 14		1	20	32
22					Aug. 22	2	5	Aug. 26	2	4	13	Sept. 15	4	5	21	33
					Aug. 22							Sept. 15		1	20	33
					Aug. 22	1	4	Aug. 27	1	5	14	Sept. 16	1	1	21	34
	Aug. 18		5		5	22	2	5	Aug. 28	2	5	15	Sept. 16	2	20	34
23					Aug. 23	1	6	Aug. 30	1	8	20	Sept. 17	1	1	18	35
					Aug. 24	1	1	Aug. 30	1	1	17	Sept. 17	2	2	19	34
					Aug. 25	1	7	Sept. 2	1	8	20	Sept. 18	1	1	16	36
	Aug. 18		7		4	Aug. 22	1	4	Aug. 26	4	4	12	Sept. 14	1	19	31
24					Aug. 23	3	5	Aug. 27	3	4	13	Sept. 15	2	1	20	32
					Aug. 23							Sept. 15		1	19	32
					Aug. 23	7	4	Aug. 27	3	4	13	Sept. 16	1	1	20	33
	Aug. 19		7		5	Aug. 23						Sept. 15	1	1	19	32
25					Aug. 25	1	4	Aug. 29	2	5	14	Sept. 16	1	1	20	33
					Aug. 26	1	4	Aug. 30	2	6	15	Sept. 16	2	1	19	33
					Aug. 28	1	5	Sept. 3	1	8	18	Sept. 16	1	1	17	31
	Aug. 23		1		6	Aug. 28	1	5	Sept. 4	1	8	18	Sept. 16	1	15	33
26					Aug. 28	1	5	Sept. 4	1	7	18	Sept. 18		1	14	32
					Aug. 28	1	5	Sept. 4	1	7	18	Sept. 18		1	14	32
					Aug. 29	1	5	Sept. 5	1	7	18	Sept. 18		1	14	32
	Aug. 24		1		6	Aug. 29	1	5	Sept. 5	1	7	18	Sept. 18		14	32
Totals and weighted averages.....		242	4.83	268	3.58	349	4.12	12.33	282	281	22.36					1 33.76

Average period for 111 males and 107 females.

The proportion of sexes under natural conditions was not determined, but among those reared in the life-history cages the males and females appeared in almost exactly equal numbers, there being 282 males and 281 females.

SEASONAL-HISTORY SUMMARY.

The cherry leaf-beetle hibernates in the adult stage. The beetles emerge from their winter quarters in the late spring, and, after feeding for a few weeks and mating, the females go to the bases of the trees and deposit their eggs in the accumulation of rubbish. In something less than two weeks the eggs hatch. The larvæ grow rapidly and in less than two weeks attain full growth, when they burrow a short distance into the ground, pass through their pupal stage, and, in from two to three weeks after entering the ground, reappear as adult beetles. These beetles feed until cold weather compels them to seek shelter for the winter.

The season of 1915 was unusually cold and wet, and this condition undoubtedly delayed the development of the insect to a considerable extent. The hibernating beetles appeared at North East on June 7. Within two weeks their numbers were noticeably diminishing, but beetles of both sexes were observed as late as August 5, and females collected at this time still contained eggs. Unfortunately the natural food plant and egg-laying habits were not learned until the 3d of August, but at this time many eggs were still unhatched. Larvæ continued to emerge until August 14, and from another lot of eggs collected August 5 larvæ were hatched as late as August 18. At the time these eggs were collected there were full-grown larvæ on the trees, and many had undoubtedly entered the ground for pupation. Larvæ were observed on the pin cherry as late as September 10, when a full-grown larva and a young third-stage larva were found on some foliage that had been brought into the laboratory two days earlier. The active feeding portion of the larval life in the cages varied from 10 to 20 days, the average being 12.33 days.

The period spent in the ground in the cages varied from 14 to 28 days, the average being 22.36 days. The total developmental period is from 45 to 50 days.

The earliest adult to emerge in the cages appeared on August 23, but the pale, newly emerged beetles were observed in the open on the 16th. On August 31 the adults of the new brood were abundant on pin cherry, while many young beetles and pupæ and a few larvæ were found in soil and leaf mold under the bushes. On September 8 adults were abundant, but by September 23 they had begun to disappear, and no pupæ could be found in the ground, although a few newly emerged adults were observed.

A PREDATORY ENEMY.

In the leaf mold at the base of wild cherry trees, in which cherry leaf-beetles were transforming in great numbers, small carabid beetles with a striking color pattern of black and yellow were also abundant. These beetles were determined by Mr. E. A. Schwarz to be a large form of *Lebia ornata* Say. (Fig. 9.) In confinement these carabids would eat pupæ and callow adults voraciously. In attacking an adult *Galerucella* the carabid would tear off one elytron and then eat the soft body tissues. In confinement one *Lebia* killed four callow *Galerucella* adults in one night; only one was eaten, but the others all had the wings on one side torn off and were more or less mutilated otherwise. When pupæ were killed nothing was left but the pupal skin.

Several other carabids were found in places where the cherry leaf-beetle transforms, but none was found feeding upon it, nor could any of them be induced to do so in confinement.

CONTROL.

PREVIOUS RECOMMENDATIONS.

There is no indication from entomological literature that any experiments to control this beetle have been conducted previous to 1915. Pettit (1898), Chittenden (1899), and O'Kane (1914) have recommended the use of Paris green and other arsenicals, doubtless basing their recommendations on their knowledge of related insects. Pettit (1898) recommended also the use of soap solution and kerosene emulsion, if spraying must be done on the trees when fruit is ripening.

EXPERIMENTS IN 1915.

When the cherry leaf-beetle appeared in the vicinity of North East, experimental spraying against the grape-berry moth was in progress at this station. Consequently no experimental work to control the beetle was undertaken until four days later, when the work in hand was finished. The effectiveness of poisoned sprays in these experiments was lessened somewhat by the fact that the beetles were feeding less heavily at the time of the application than they had been immediately after their arrival in this region.

All spraying experiments made against beetles of the spring migration were in two small orchards belonging to the late J. L. Spofford and M. D. Phillips, except some small cage experiments which were conducted in the insectary yard. These two orchards adjoined each other and were alike in so many ways that they were treated as

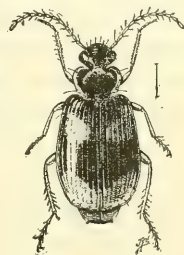


FIG. 9.—*Lebia ornata*, a predatory enemy of the cherry leaf-beetle. Much enlarged. (Original.)

one orchard. The trees were 4 years old and of Early Richmond and Montmorency varieties. The former variety was used almost exclusively in the experiments.

ARSENATE OF LEAD.

KILLING STRENGTH.

In order to determine the amount of poison necessary to kill the cherry leaf-beetle, trees were sprayed with various strengths of arsenate of lead on June 11. Two, 3, 4, 5, and 6 pounds were used to 50 gallons of water; one-half pound of lime was added to each of these mixtures. In addition mixtures at the rate of 3 pounds to 50 gallons and 5 pounds to 50 gallons, to which had been added $1\frac{1}{2}$ gallons of molasses, were applied. To supplement the conclusions on the effect of the various mixtures drawn from observation of the beetles on the trees sprayed, about 100 beetles were confined in a bag on a branch of one tree sprayed by each of the different mixtures. No burning of foliage followed the application of any of the solutions used.

The various arsenate of lead and lime mixtures were ineffective in killing many of the beetles. The stronger solutions—4, 5, and 6 pounds to 50 gallons—were repellent and consequently to an extent protected the trees. The weaker solutions—2 and 3 pounds to 50 gallons—were ineffective even as repellents, for the beetles confined in bags on trees thus sprayed fed without apparent inconvenience. The beetles confined in bags on the trees sprayed with the stronger solutions, especially 5 and 6 pounds to 50 gallons, fed but little, although they were confined for a week. A negligible number of beetles, never 10 per cent, was found dead in the bags.

The sweetened arsenate of lead used at the rate of 3 pounds to 50 gallons was comparatively effective, although far from satisfactory. There were some dead beetles on the ground, and 40 per cent of those in the bag were dead. There was a good deal of feeding on the tree.

The sweetened arsenate of lead applied at the rate of 5 pounds to 50 gallons was effective. There were many dead beetles on the ground under the trees, and of the beetles in the bag 96 per cent were dead when examination was made three days after spraying. The trees sprayed with this mixture were effectively protected from injury.

On June 14 a tree that had been sprayed with 2 pounds of arsenate of lead to 50 gallons three days previous was resprayed with the same mixture to test the effectiveness of a double spray with a weak solution. The application was ineffective.

A second comparison of the sweetened and unsweetened mixtures of arsenate of lead was made June 19. The only strength of poison used was 5 pounds to 50 gallons of water, the weakest solution

effective in the first experiment. No lime was added to the unsweetened mixture and the molasses was used at the same rate as formerly, viz, $1\frac{1}{2}$ gallons to 50 gallons of water.

Dead beetles were found under all the trees sprayed, but they were far more numerous under the trees sprayed with the sweetened mixture than under those sprayed with the unsweetened mixture. Also there was less feeding on the trees sprayed with the sweetened arsenate, although there was comparatively little on either, while the unsprayed check was loaded with beetles.

EFFECT OF LIME IN COMBINATION WITH ARSENATE OF LEAD.

To test the effect of lime as a repellent when used in sprays in combination with arsenate of lead, beetles were caged on parts of a tree in the insectary yard sprayed with lime water at the rate of 1 pound to 50 gallons and 5 pounds to 50 gallons. In both cages the beetles fed as freely on the leaves thus sprayed as on those that had not been sprayed.

CONTACT SPRAYS.

SOAP-CARBOLIC ACID SOLUTION.

A solution of fish-oil soap, 10 pounds to 50 gallons of water, to which three-fourths of a pint of carbolie acid was added, was tried as a contact spray on June 11. Immediately upon the application of this solution the majority of the beetles fell from the tree, apparently dead. Several hundred of these were gathered from the ground, placed in vials, and taken to the insectary. By the evening of the next day practically all of the beetles were active again and apparently uninjured by the spray. The solution is not permanently repellent, for the trees thus sprayed were badly attacked again two days after the application of the spray. This spray was not injurious to foliage.

NICOTINE SULPHATE.

A solution of 40 per cent nicotine sulphate at the rate of 1 part to 600 parts of water, to which was added fish-oil soap at the rate of 2 pounds to 50 gallons of liquid, was used as a contact spray on June 11. The effect was apparently similar to that of the soap-carbolie acid solution; some of the beetles escaped by flight but the majority fell from the tree when hit by the spray and soon appeared dead. Several hundred of them were gathered and taken to the insectary to test the permanence of this state. They were kept under observation for five days without showing any signs of life.

In order to compare the effectiveness of nicotine sulphate without soap, a large tree in the insectary yard was sprayed with nicotine

sulphate (40 per cent) on June 27. Of the beetles that fell from the tree, 318 were collected on a sheet and placed in a ventilated cage in the insectary. Five days later practically all of them, over 98 per cent, still showed no signs of life.

Weaker dilutions of 40 per cent nicotine sulphate were tested on September 9 on beetles of the new brood. Pin-cherry trees were sprayed, because at this time the beetles were feeding on no other. The following strengths were used: One part of nicotine sulphate to 800, 1,000, and 1,200 parts of water, respectively. Soap was added as in the first experiment at the rate of 2 pounds to 50 gallons of liquid. None of these strengths was effective, and none of them showed the immediate effects that followed spraying with a solution at the strength of 1 to 600. Many of the beetles hit with the sprays of the strengths of 1 to 800 and 1 to 1,000 became very sluggish and in 10 or 15 minutes appeared dead. Very few of those hit by the 1 to 1,200 solution appeared injured at all. About 150 beetles were collected from trees sprayed with each solution and placed in jars in the insectary. On the evening of September 10, 60 per cent of the beetles sprayed with the 1 to 800 solution, 68 per cent of those sprayed with the 1 to 1,000 solution, and 96 per cent of those sprayed with the 1 to 1,200 solution were active and feeding.

RESULTS FROM SPRAYING BY GROWERS.

Immediately following the advent of the cherry leaf-beetle in the Lake Erie grape belt there was unusual spraying activity to check it. Arsenate of lead was used in most instances, but applications of lime-sulphur, Bordeaux mixture, nicotine sulphate, soap, and lime, used in various combinations and at various strengths, were also made. The results were various.

Orchards in which arsenate of lead had been used at the rate of 5 pounds to 50 gallons of water, with and without lime, were observed by the writers. In these orchards the trees were generally quite well protected, although few dead beetles were found on the ground under the trees. Where weaker solutions of poison were used the results were far from satisfactory in the orchards observed. The use of sweetened arsenate of lead was observed in only one orchard outside of the experimental plats, and in this instance it was entirely unsuccessful. The spray was applied immediately before a heavy rain, which washed it all off.

A number of combination sprays in which 40 per cent nicotine sulphate was used were successful. The nicotine sulphate was sometimes used at rates as strong as 1 to 400. The following is a typical effective mixture: Arsenate of lead, 3 pounds; 40 per cent nicotine sulphate, 1 pound; laundry soap, 2 bars; water, 50 gallons.

Hydrated lime, dusted on trees by hand, was used as a protective measure, and in some instances appeared to be effective.

SUMMARY OF EXPERIMENTS.

From the experiments and observations described, the following conclusions may be drawn:

Arsenate of lead must be used at a rate of not less than 5 pounds to 50 gallons of water to be effective in protecting trees from injury by the cherry leaf-beetle. A mixture to which molasses was added at the rate of $1\frac{1}{2}$ gallons to 50 gallons of the mixture was effective in killing practically all of the beetles which fed upon the trees on which this mixture was applied. This addition of sweetening to the arsenate has the serious disadvantage of making the spray easily washed off by rains. Arsenate of lead used without molasses was less effective in protecting the trees, although it killed some beetles and it was to an extent repellent to them. Lime in the amount in which it is added to an arsenate-of-lead spray was not repellent.

Forty per cent nicotine sulphate applied with water at the rate of 1 to 600, with or without soap, was effective as a contact spray. Weaker dilutions of nicotine sulphate and soap-carbolic acid solutions, although apparently effective at the time of application, did not have a permanent effect.

CONTROL OF LARVÆ.

If the larvæ fed on a cultivated plant, control measures might be directed against it, thus preventing the adults from developing in destructive numbers. But it feeds on a wild plant that is usually present where control measures can not be applied, often on land that is in no way controlled by the fruit grower, and not even in the immediate vicinity of fruit farms. Nevertheless the clearing up of cut-over timberland and the destruction of the wild hosts of the larva of this beetle would greatly limit its possibilities of destructiveness. Should the cherry leaf-beetle become a permanent pest, cooperative work along this line might be advisable.

RECOMMENDATIONS.

Spray practice for the control of the cherry leaf-beetle at the time of its next appearance in economic numbers can not be absolutely determined from the foregoing experiments. The numbers of the beetles, the duration of the migration, and the weather conditions at the time must qualify any recommendation. More extensive experiments also might modify the results.

Nicotine sulphate, while temporarily effective, does not prevent a new invasion of an orchard on the day following its application. However, its use in peach orchards is recommended, for the greater

strengths of arsenate of lead would be likely to cause severe injury to peach foliage. The addition of 2 pounds of soft soap or 1 pound of hard soap to 50 gallons of the mixture has been generally found to increase the effectiveness of the nicotine sulphate.

Sweetened arsenate of lead is recommended for cherry trees because of its efficiency in killing the beetles and because its effect is continuous in favorable weather. Rain destroys the effectiveness of this spray. The combination found most useful is 5 pounds of arsenate of lead, $1\frac{1}{2}$ gallons of molasses, and 50 gallons of water.

If the beetle migration should occur during a rainy period, the unsweetened arsenate of lead might be most useful.

In applying a poison spray care must be taken to cover the underside of the leaves where the beetles feed. In some instances it may be necessary to spray only young cherry trees or older trees of the thin-leaved varieties. In large orchards into which the beetles are migrating in great numbers it is advisable to spray first the trees most susceptible to attack, for during the season of 1915 the maximum injury occurred immediately after the first arrival of the beetles. In no case should the sweetened arsenate of lead be used with Bordeaux mixture as a combination spray, for burning of foliage is likely to result.

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BULLETIN No. 353

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

March 16, 1916

MOISTURE CONTENT AND SHRINKAGE OF FORAGE AND THE RELATION OF THESE FACTORS TO THE ACCURACY OF EXPERIMENTAL DATA.

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Forage-Crop Investigations.¹

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INTRODUCTION.

Agronomic literature contains but little in the way of well-planned investigations on the subject of the moisture content of different forage plants either green or cured, a matter which is intimately related in farm practice to the proper handling and wise marketing of forage crops and in investigational work to the correct interpretation of yield data. This subject is of sufficient importance to justify much more attention than has previously been given to it by experimenters. Careful investigators have long recognized that many of the published data on forage crops are inaccurate, on account of the uncertain amount of water included in the yields.

The term "air dry," as used in the investigations described in the following pages, refers to that stage of curing when the humidity of the forage and the humidity of the atmosphere have reached a state of equilibrium. The percentage of moisture in the forage when air dry of course varies with the changes in atmospheric humidity,

¹ Messrs. W. J. Morse, H. L. Westover, M. W. Evans, A. B. Cron, and R. E. Getty, members of the staff of the Office of Forage-Crop Investigations, have contributed quite largely to this publication by their assistance in collecting and preparing records of the numerous samples required.

but this variation is within rather narrow limits. The term "field cured" is more indefinite, denoting that condition of forage which obtains in general farm practice when the hay or fodder is considered sufficiently well cured or dried so that it will not spoil when placed in bales, stacks, or in a haymow. In this stage the forage is very seldom completely air dry.

Most publications on forage crops use the term "field cured" to denote the condition of the forage under consideration, but such a term does not imply a uniform percentage of moisture, and little or no care has ever been used to indicate even approximately the moisture content of the forage when the yields were determined. It is, therefore, impossible to interpret correctly many data found in such publications.

The variation in the moisture content of forage when yields are taken is often greater than the actual difference in yield that we may expect from improved varieties or improved methods. There is little dependence therefore to be placed in experimental results along these lines until this factor of error is eliminated, or at least greatly reduced. The data presented in this bulletin are sufficient to suggest a remedy for this difficulty, and it is hoped that experimenters will consider carefully the method here indicated.

Aside from the experimental value of this work, it has an economic significance, in that it points out the relative weight value of forages at different stages of maturity. However, the economic side of the question is not discussed in detail and is given only as it forms a part of the experimental data presented.

GENERAL PLAN OF THE EXPERIMENTS.

During 1914 a series of experiments was carried out to secure data on which to base a sampling system that would give greater accuracy to field tests in forage experiments. In connection with the efficiency of the sample method, investigations were also carried on to determine the amount of moisture in forage plants at different stages of development, the variation in moisture content due to locality and to cutting at different times of the day, and the differences in loss of weight when samples are dried in the sun as compared with those dried in the shade. Information was also secured on the rate of moisture loss in forage in the early stages of curing and the changes in moisture content of hay stored in bales and loose in a barn.

In conducting the experiments at the various places the methods followed were the same or varied only in minor details. Half-bushel and bushel cotton bags were used to receive all samples except the largest, for which common burlap grain bags having a capacity of 2 bushels were used. For inclosing the bales of hay a close-weave burlap was used. In taking samples of field-cured forage, care was

used to have each sample representative of the entire crop. Material from the outside as well as from the middle and bottom of the wind-rows or shocks was included.

Samples of green material were taken by cutting the plants either by hand or with machinery, each sample including only that part of the plant that is used in making hay or fodder. The samples of different sizes in both the field-cured and green material were replicated five or six times, and each sample was marked with a tag bearing a number and other data necessary for identification. In taking samples, the work was done as quickly as possible, to avoid loss in weight by evaporation. Each sample as soon as prepared was weighed immediately.

After the samples ¹ were placed in the containers and weighed, they were stored in a favorable place to facilitate further drying and at the same time were given protection from rain.

In ascertaining the total water and dry-matter content of the various samples, determinations were made by the usual method of oven drying. For this purpose a special oven having a capacity of 164 cubic feet was built. Steam heat under pressure was used and a temperature of 100° C., or a little above, was maintained.

In the following account, the outline for each experiment is given as it was carried out at the various stations, and this outline is followed by a tabulated statement of the original data from which the summaries are prepared and conclusions drawn.

USE OF SAMPLES IN CORRECTING FORAGE YIELDS.

McKee, in the *Journal of the American Society of Agronomy*,² gives a general discussion of moisture as a factor of error in determining forage yields, wherein it is suggested that forage-yield data can be made much more nearly comparable if small samples taken at the time of weighing field-cured or green material are used in determining the moisture content of the material and these data used in reducing the yield either to an air-dry or to a dry-matter basis.

In the experiments described in the present bulletin, the efficiency of correcting ordinary green and field-cured forage weights with 2, 4, 6, 8, 12, or 16 pound samples was determined with the following crops: At Arlington Farm, Va., alfalfa and a mixture of tall oat-grass and orchard grass; at Chico, Cal., alfalfa; at New London, Ohio, timothy; at Amarillo, Tex., sorghum; and at Hays, Kans., sorghum. To provide a basis for checking up the moisture loss in small samples, 100 pounds of ordinary field-cured forage were taken from the shock

¹ The samples of tall oat-grass and orchard grass at Arlington Farm, Va., were prepared by H. N. Vinall and H. L. Westover; the alfalfa at Arlington Farm, Va., by W. J. Morse; the alfalfa at Chico, Cal., by Roland McKee; the timothy at New London, Ohio, by M. W. Evans; the sorghums at Amarillo, Tex., by A. B. Cron, and at Hays, Kans., by R. E. Getty.

² McKee, Roland. Moisture as a factor of error in determining forage yields. *In Jour. Amer. Soc. Agron.*, v. 6, no. 3, p. 113-117, 1914.

or windrow and 500 pounds of green forage were taken immediately after cutting and placed on a canvas to prevent loss of weight other than moisture. When the forage on the canvas had become sufficiently dry, these bulk lots were placed in burlap bags and kept in an open shelter until they ceased to lose weight.

Composite samples, 2, 4, 6, and 8 pounds in size, of field-cured forage, part from the outside and part from the inside of shocks, were secured at the same time and from the same material as the 100-pound lot before mentioned. These samples were weighed at once and put aside to become perfectly air dry. Samples, 4, 8, 12, and 16 pounds in size, of green forage were taken immediately after cutting and were treated similarly. Samples were replicated five or six times to check the variation due to sampling. All samples were taken at the stage of maturity generally recognized as the proper cutting time for each crop. The samples were kept in a shelter and weighed at intervals until they ceased to lose weight. They were then shipped to Washington, D. C., for the purpose of reducing them to a moisture-free state in the drying oven. The intention was to secure samples of timothy at both New London, Ohio, and Arlington Farm, Va., so that each crop would be handled at two stations, but an unfavorable season caused a failure of the timothy crop at Arlington Farm, and it was found necessary to substitute there the mixture of tall oat-grass and orchard grass.

In Table I an attempt has been made to arrange the data so as to make the conclusions to be derived from them as clear as possible. Column 1 contains the number under which the identity of the sample was preserved from the time it was prepared until it was finally weighed from the drying oven.

Column 2 gives the original weight of the sample, whether green or field cured.

Column 3 gives the weight of the sample at a date between the time it was prepared and the date when it was considered air dry. This column is intended to show about what time is required for each sample to lose most of its moisture, that is, when it was drier than field cured, but in most cases not yet air dry. This column is blank in sections A and B because no weights were obtained between the date of cutting and the date when the samples were completely air dry.

Column 4 carries the air-dry weight of the sample. In some cases this was the weight obtained just before the sample was placed in the drying oven, but where an earlier weighing made at the field station showed the sample to be practically as dry at that time, the earlier weight is given.

Column 5 gives the weight of the samples oven dry and represents the dry matter contained in each sample as nearly as it can be determined in an ordinary oven.

Column 6 carries a statement of the percentage of moisture in each of the original samples, as determined by the difference between the original and the oven-dry weights. It is recognized that this loss may not necessarily be exclusively water. Slight losses may have taken place through volatilization of substances other than water or through fermentation due to enzymes or bacteria, but such losses are undoubtedly small when the hay has been quickly cured. The percentages as given are determined by using the original weights of the samples as the base. It is recognized that this practice is open to criticism, owing to the fact that the original weights vary in relative importance, due to the differing percentages of moisture which the samples contain. This criticism is of little importance in the present case, however, since the percentage of moisture is very nearly the same in each group where a comparison is made. The use of the absolute dry matter as a base from which to figure the percentages was tried, but this method seemed impracticable, because it makes the percentages so at variance with the moisture percentages as usually given. Column 6 also gives the means of groups of three and groups of five or six samples, with their probable errors. In tables where there are only five samples in each class the second group of three represented by the second mean includes the remaining two samples and the one next above, which has already been considered in the first group. For example, in section A the first "mean of 3" is based on samples 1, 2, and 3, and the second "mean of 3" on samples 3, 4, and 5. These means are set in black-faced type, so that they will be apparent at a glance. The consistency in the percentages of moisture in each set of samples is remarkable. In only one case has the probable error for the group of six samples exceeded 1 per cent, and the probable error for a single sample averaged considerably less than 1 per cent, although in exceptional cases it approached 2.5 per cent. The probable error was chosen as the most efficient measure of the comparative reliability of the different sizes of samples and methods of sampling. Since the moisture is here stated in percentages, means of practically the same size are dealt with, and the need for a term like the coefficient of variability is lacking.

Column 7, as shown by the heading, is a record of the percentage of moisture in the air-dry material, the weight of which is shown in column 4.

Column 8 gives the percentage of moisture which was lost in reducing the material from its original state to an air-dry condition. The base on which this percentage was calculated is the weight of the original material given in column 2. The actual losses of weight in 100 pounds of field-cured and 500 pounds of green material under the same conditions as those surrounding the samples are given following the tabulation of sample weights.

TABLE I.—*Comparison of different-sized samples of forage.*

SECTION A.—GREEN ALFALFA COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, Oct. 16; air-dry material, Feb. 2.]

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 1.....	64	.....	18.0	16.0	75.0	11.1	71.9
No. 2.....	64	.....	18.0	16.5	74.2	8.3	71.9
No. 3.....	64	.....	18.5	16.0	75.0	13.5	71.1
Mean of 3.....	.....	.....	.....	.....	74.7±0.148	.....	.....
No. 4.....	64	.....	20.0	18.0	71.9	10.0	68.8
No. 5.....	64	.....	18.5	16.5	74.2	10.8	71.1
Mean of 3.....	.....	.....	.....	.....	73.7±.510	.....	.....
Mean of 5.....	.....	.....	.....	.....	74.1±.344	10.7±0.510	71.0±0.237
Error of 1.....	.....	.....	.....	.....	±.769	.....	.....
No. 6.....	128	.....	38.0	34.0	75.4	10.5	70.3
No. 7.....	128	.....	35.0	31.5	75.4	10.0	72.7
No. 8.....	128	.....	35.0	31.5	75.4	10.0	72.7
Mean of 3.....	.....	.....	.....	.....	74.7±.367	.....	.....
No. 9.....	128	.....	36.5	32.5	74.6	10.9	71.5
No. 10.....	128	.....	36.0	32.0	75.0	11.1	71.9
Mean of 3.....	.....	.....	.....	.....	75.0±.127	.....	.....
Mean of 5.....	.....	.....	.....	.....	74.8±.225	10.5±.129	71.8±.259
Error of 1.....	.....	.....	.....	.....	±.501	.....	.....
No. 11.....	192	.....	51.5	46.0	76.0	10.7	73.2
No. 12.....	192	.....	52.5	46.5	75.8	11.2	72.7
No. 13.....	192	.....	54.0	48.0	75.0	11.1	71.9
Mean of 3.....	.....	.....	.....	.....	75.6±.168	.....	.....
No. 14.....	192	.....	53.5	47.5	75.3	11.2	72.2
No. 15.....	192	.....	52.5	47.0	75.5	10.5	72.7
Mean of 3.....	.....	.....	.....	.....	75.2±.081	.....	.....
Mean of 5.....	.....	.....	.....	.....	75.5±.160	10.9±.107	72.5±.136
Error of 1.....	.....	.....	.....	.....	±.248	.....	.....
No. 16.....	256	.....	65.0	58.0	77.3	10.8	74.6
No. 17.....	256	.....	67.5	59.5	76.8	11.9	73.6
No. 18.....	256	.....	68.5	61.5	76.0	10.2	73.2
Mean of 3.....	.....	.....	.....	.....	76.7±.207	.....	.....
No. 19.....	256	.....	67.5	61.0	76.2	9.6	73.6
No. 20.....	256	.....	68.5	60.5	76.4	11.7	73.2
Mean of 3.....	.....	.....	.....	.....	76.2±.063	.....	.....
Mean of 5.....	.....	.....	.....	.....	76.5±.155	10.8±.251	73.6±.155
Error of 1.....	.....	.....	.....	.....	±.347	.....	.....

SECTION B.—FIELD-CURED¹ ALFALFA COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, Oct. 20; air-dry material, Feb. 2.]

No. 21.....	32	.....	32.5	29.0	9.3	9.6	.....
No. 22.....	32	.....	33.0	29.5	7.7	9.6	.....
No. 23.....	32	.....	32.5	29.0	9.3	9.6	.....
Mean of 3.....	.....	.....	.....	.....	8.8±0.294	.....	.....
No. 24.....	32	.....	32.0	29.0	9.3	9.3	.....
No. 25.....	32	.....	32.0	29.0	9.3	9.3	.....
Mean of 3.....	.....	.....	.....	.....	9.3±0	.....	.....
Mean of 5.....	.....	.....	.....	.....	9.0±.193	9.5±0.045	.....
Error of 1.....	.....	.....	.....	.....	±.432	.....	.....

¹Owing to unfavorable weather conditions, this material was moved into a greenhouse shortly after it was cut, and the curing was finished there. This explains the unusual dryness of these samples. They are not to be considered field cured, and the percentage of moisture lost in air drying is therefore disregarded.

TABLE I.—Comparison of different-sized samples of forage—Continued.

SECTION B.—FIELD-CURED ALFALFA COLLECTED AT ARLINGTON FARM—Continued.

Sample.	Weight.				Moisture.		
	Original.	Inter-mediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 26.....	64		64.0	57.5	10.1	10.1	
No. 27.....	64		64.5	57.5	10.1	10.7	
No. 28.....	64		63.5	57.0	10.8	10.2	
Mean of 3.....					10.3± .130		
No. 29.....	64		63.5	57.0	10.8	10.2	
No. 30.....	64		63.0	57.5	10.2	8.7	
Mean of 3.....					10.6± .110		
Mean of 5.....					10.4± .099	10.0± .203	
Error of 1.....					± .221		
No. 31.....	96		92.5	84.0	12.4	9.1	
No. 32.....	96		94.5	85.0	11.4	10.0	
No. 33.....	96		92.5	83.5	13.0	9.7	
Mean of 3.....					12.3± .258		
No. 34.....	96		93.0	85.0	11.4	8.6	
No. 35.....	96		92.0	83.0	13.5	9.8	
Mean of 3.....					12.6± .349		
Mean of 5.....					12.3± .257	9.4± .156	
Error of 1.....					± .576		
No. 36.....	128		126.5	113.0	11.5	10.6	
No. 37.....	128		128.0	113.0	11.5	11.5	
No. 38.....	128		127.0	112.5	12.1	11.3	
Mean of 3.....					11.7± .110		
No. 39.....	128		126.0	112.0	12.3	11.1	
No. 40.....	128		124.5	111.5	12.8	10.3	
Mean of 3.....					12.4± .115		
Mean of 5.....					12.0± .181	11.0± .135	
Error of 1.....					± .406		

SECTION C.—GREEN ALFALFA COLLECTED AT CHICO, CAL.

[Dates of weighing: Original material, June 11; intermediate, June 30; air-dry material, July 23.]

No. 501.....	60.5	17.50	17.25	16.0	73.6	7.2	71.5
No. 502.....	60.5	17.00	16.75	15.5	74.4	7.5	72.3
No. 503.....	60.5	16.00	15.75	14.5	76.0	7.8	74.0
Mean of 3.....					74.7± 0.389		
No. 504.....	60.5	16.25	16.25	15.0	75.2	7.5	73.2
No. 505.....	60.5	16.50	16.00	14.5	76.0	9.3	73.5
No. 506.....	60.5	16.00	16.00	15.0	75.2	6.2	73.2
Mean of 3.....					75.5± .148		
Mean of 6.....					75.1± .258	7.6± 0.253	73.0± 0.249
Error of 1.....					± .576		
No. 507.....	123.2	33.95	32.70	29.0	76.5	11.2	72.5
No. 508.....	123.2	31.95	30.45	27.0	78.1	11.4	73.3
No. 509.....	124.5	36.25	32.75	30.0	75.8	8.4	73.7
Mean of 3.....					76.8± .375		
No. 510.....	123.2	34.20	32.45	29.0	76.4	10.7	73.7
No. 511.....	124.5	35.00	33.25	30.0	75.8	9.6	73.3
No. 512.....	124.5	33.75	30.25	28.0	77.5	7.4	75.7
Mean of 3.....					76.6± .275		
Mean of 6.....					76.7± .234	9.8± .407	74.2± .258
Error of 1.....					± .574		

TABLE I.—*Comparison of different-sized samples of forage—Continued.*

SECTION C.—GREEN ALFALFA COLLECTED AT CHICO, CAL.—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 513.....	187.2	50.20	45.20	40.5	78.4	10.2	75.9
No. 514.....	187.2	50.20	45.70	41.0	78.1	10.2	75.6
No. 515.....	187.2	51.70	46.20	41.5	77.8	10.0	75.3
Mean of 3.....					78.1± .095		
No. 516.....	187.2	52.95	48.20	43.0	77.0	10.7	74.3
No. 517.....	187.2	50.95	46.70	41.5	77.8	11.0	75.1
No. 518.....	187.2	50.20	47.20	42.5	77.3	9.8	74.8
Mean of 3.....					77.4± .125		
Mean of 6.....					77.7± .129	10.3± .113	75.2± .144
Error of 1.....					± .316		
No. 519.....	251.2	72.70	61.45	55.5	77.9	9.6	75.5
No. 520.....	251.2	73.45	62.95	56.5	77.5	10.1	74.9
No. 521.....	251.2	72.20	59.95	53.5	78.7	10.5	76.1
Mean of 3.....					78.0± .195		
No. 522.....	251.2	69.95	60.70	54.5	78.3	10.1	75.7
No. 523.....	251.2	76.95	62.20	56.0	77.7	10.0	75.2
No. 524.....	251.2	71.70	62.20	55.5	77.9	10.7	75.2
Mean of 3.....					78.0± .098		
Mean of 6.....					78.0± .109	10.2± .098	75.4± .108
Error of 1.....					± .267		

SECTION D.—FIELD-CURED ALFALFA COLLECTED AT CHICO, CAL.

[Dates of weighing: Original material, June 13; intermediate, June 30; air-dry material, July 23.]

No. 525.....	28.5	24.00	24.00	22.5	21.0	6.2	15.8
No. 526.....	28.5	25.25	25.25	23.5	17.5	7.0	11.4
No. 527.....	28.5	24.75	25.00	23.0	19.0	8.0	12.3
Mean of 3.....					19.2± 0.511		
No. 528.....	28.5	23.50	23.75	22.0	22.5	7.3	16.6
No. 529.....	28.5	24.00	25.50	22.5	21.0	11.7	10.5
No. 530.....	27.2	23.70	23.70	21.0	22.7	11.3	12.8
Mean of 3.....					22.0± .297		
Mean of 6.....					20.6± .538	8.6± 0.587	13.2± 0.611
Error of 1.....					± 1.247		
No. 531.....	59.2	51.20	51.45	46.5	21.2	9.5	13.0
No. 532.....	59.2	49.95	50.45	45.5	23.0	9.6	14.8
No. 533.....	59.2	48.45	49.20	44.0	25.5	10.4	16.8
Mean of 3.....					23.2± .685		
No. 534.....	59.2	48.70	48.20	43.5	26.3	9.7	18.6
No. 535.....	59.2	50.45	50.70	46.0	22.0	9.3	14.3
No. 536.....	59.2	48.45	48.70	44.0	25.5	9.8	17.7
Mean of 3.....					24.6± .727		
Mean of 6.....					23.9± .585	9.7± .095	15.9± .548
Error of 1.....					± 1.308		
No. 537.....	91.2	75.70	75.45	68.5	24.8	9.1	17.2
No. 538.....	91.2	78.70	77.95	71.0	22.0	9.0	14.5
No. 539.....	91.2	78.20	77.95	71.0	22.0	9.0	14.5
Mean of 3.....					22.9± .514		
No. 540.....	91.2	77.45	76.70	69.5	23.5	9.5	15.9
No. 541.....	91.2	79.95	80.20	72.5	20.3	9.6	12.1
No. 542.....	91.2	79.20	78.95	71.5	21.5	9.4	13.4
Mean of 3.....					21.8± .514		
Mean of 6.....					22.4± .399	9.3± .067	14.6± .452
Error of 1.....					± .977		

TABLE I.—Comparison of different-sized samples of forage—Continued.

SECTION D.—FIELD-CURED ALFALFA COLLECTED AT CHICO, CAL.—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 543.....	114.0	96.25	99.00	87.5	23.3	11.6	13.1
No. 544.....	116.5	105.00	105.75	94.25	17.7	10.9	9.2
No. 545.....	115.25	101.50	102.75	91.75	20.5	10.7	10.8
Mean of 3.....					20.5± .971		
No. 546.....	115.75	100.50	101.25	90.00	22.3	11.2	12.6
No. 547.....	115.75	96.75	97.75	85.75	21.0	12.3	15.6
No. 548.....	116.25	92.75	94.00	82.25	29.3	12.5	19.1
Mean of 3.....					24.2±1.421		
Mean of 6.....					22.4±1.454	11.5± .186	13.4± .089
Error of 1.....					±2.402		

SECTION E.—GREEN TALL OAT-GRASS AND ORCHARD GRASS¹ COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, June 2; intermediate, July 3; air-dry material, July 18.]

No. 41.....	64	22.0	22.5	19.0	70.3	15.5	65.5
No. 42.....	64	21.5	21.5	18.0	71.8	16.2	66.4
No. 43.....	64	22.0	22.5	19.0	70.3	15.5	65.5
Mean of 3.....					70.8±0.275		
No. 44.....	64	22.0	21.5	18.0	71.8	16.2	66.4
No. 45.....	64	21.5	22.0	18.5	71.1	15.8	65.6
Mean of 3.....					71.1± .239		
Mean of 5.....					71.1± .203	15.8±0.095	65.9±0.129
Error of 1.....					± .435		
No. 46.....	128	45.5	46.0	38.0	70.3	17.4	64.1
No. 47.....	128	43.0	42.0	35.0	72.6	16.6	67.2
No. 48.....	128	43.0	43.0	35.5	72.2	17.3	66.4
Mean of 3.....					71.7± .391		
No. 49.....	128	46.5	45.5	37.5	70.7	17.5	64.4
No. 50.....	128	43.0	44.0	38.0	71.9	18.1	65.6
Mean of 3.....					71.6± .252		
Mean of 5.....					71.5± .268	17.4± .145	65.5± .353
Error of 1.....					± .599		
No. 51.....	128	46.0	48.0	38.5	69.9	19.7	62.5
No. 52.....	128	46.5	48.0	36.5	71.5	23.9	62.5
No. 53.....	128	43.0	42.0	34.5	73.0	17.8	67.2
Mean of 3.....					71.5± .493		
No. 54.....	128	47.5	47.5	38.5	69.9	18.9	62.8
No. 55.....	128	46.8	48.0	39.0	69.6	18.7	62.5
Mean of 3.....					70.8± .599		
Mean of 5.....					70.8± .391	19.8± .204	63.5± .358
Error of 1.....					± .873		
No. 56.....	192	63.0	65.0	53.0	72.4	18.4	66.2
No. 57.....	192	65.0	64.5	53.5	72.2	17.0	66.4
No. 58.....	192	63.0	65.5	54.0	71.9	17.5	65.9
Mean of 3.....					72.2± .081		
No. 59.....	192	63.5	64.5	53.0	72.4	17.7	66.4
No. 60.....	192	63.5	64.5	53.5	72.2	17.0	66.4
Mean of 3.....					72.2± .081		
Mean of 5.....					72.2± .056	17.5± .157	66.3± .060
Error of 1.....					± .124		

¹ Samples 46, 47, 48, 49, and 50 were cured in the shade for comparison with the other group of 8-pound samples which were cured in the sun.

TABLE I.—Comparison of different-sized samples of forage—Continued.

SECTION E.—GREEN TALL OAT-GRASS AND ORCHARD GRASS COLLECTED AT ARLINGTON FARM—CON.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 61.....	256	83.0	82.8	68.5	73.2	17.1	67.6
No. 62.....	256	83.3	82.8	68.0	73.4	17.8	67.6
No. 63.....	256	88.0	89.5	73.5	71.3	17.7	65.1
Mean of 3.....					72.6±.369		
No. 64.....	256	84.5	82.5	68.0	73.4	17.6	67.8
No. 65.....	256	77.5	78.0	64.0	75.0	17.8	69.5
Mean of 3.....					73.2±.590		
Mean of 5.....					73.3±.355	17.6±.079	67.5±.424
Error of 1.....					±.793		

SECTION F.—FIELD-CURED TALL OAT-GRASS AND ORCHARD GRASS COLLECTED AT ARLINGTON FARM.

[Dates of weighing: Original material, June 6; intermediate, July 3; air-dry material, July 18.]

No. 66.....	32	26.0	26.5	22.0	31.2	16.8	17.1
No. 67.....	32	27.0	27.0	22.5	29.7	16.6	15.5
No. 68.....	32	26.5	26.0	21.5	32.8	17.3	18.6
Mean of 3.....					31.2±0.488		
No. 69.....	32	26.5	27.0	22.0	31.2	18.5	15.5
No. 70.....	32	26.0	26.0	21.0	34.3	19.1	18.6
Mean of 3.....					32.8±.493		
Mean of 5.....					31.8±.409	17.7±0.295	17.1±0.418
Error of 1.....					±.914		
No. 71.....	64	53.5	52.5	43.5	32.0	24.3	17.9
No. 72.....	64	57.0	57.0	47.5	25.8	21.6	10.8
No. 73.....	64	53.5	53.0	42.5	33.6	19.8	17.1
Mean of 3.....					30.5±1.310		
No. 74.....	64	56.0	55.5	46.5	27.3	16.2	13.2
No. 75.....	64	56.0	56.0	46.5	27.3	17.7	11.7
Mean of 3.....					29.4±1.157		
Mean of 5.....					29.2±.750	19.9±.861	14.1±.863
Error of 1.....					±1.677		
No. 76.....	96	84.0	82.5	68.0	29.2	17.6	14.0
No. 77.....	96	83.5	84.5	70.5	26.6	16.6	12.0
No. 78.....	96	83.0	82.0	67.5	29.6	17.6	14.5
Mean of 3.....					28.5±.518		
No. 79.....	96	83.3	83.0	68.5	28.5	17.4	13.5
No. 80.....	96	86.3	87.0	72.0	25.0	17.2	9.3
Mean of 3.....					27.7±.764		
Mean of 5.....					27.8±.522	17.3±.112	12.7±.566
Error of 1.....					±1.167		
No. 81.....	128	113.0	116.5	93.5	26.9	19.7	9.0
No. 82.....	128	116.5	116.5	94.0	26.6	19.4	9.0
No. 83.....	128	115.0	116.0	93.0	27.4	19.8	9.3
Mean of 3.....					27.0±.129		
No. 84.....	128	114.0	114.5	93.0	27.4	18.8	10.5
No. 85.....	128	115.5	115.5	93.5	26.9	19.1	9.7
Mean of 3.....					27.2±.093		
Mean of 5.....					27.2±.136	19.4±.113	9.5±.169
Error of 1.....					±.304		

TABLE I.—Comparison of different-sized samples of forage—Continued.

SECTION G.—GREEN TIMOTHY COLLECTED AT NEW LONDON, OHIO.

[Dates of weighing: Original material, July 10; intermediate, Sept. 2; air-dry material, Sept. 28.]

Sample.	Weight.				Moisture.		
	Original.	Inter-mediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 401.....	64	33	31	26.5	58.6	14.5	51.3
No. 402.....	67	33	32	27.5	59.0	14.0	52.3
No. 403.....	63	32	31	26.0	58.8	16.1	50.8
Mean of 3.....					58.8±0.063		
No. 404.....	65	33	33	28.0	57.0	15.1	49.3
No. 405.....	64	33	32	27.0	57.9	15.6	50.0
No. 406.....	68	35	34	29.0	57.4	14.7	50.0
Mean of 3.....					57.4±.144		
Mean of 6.....					58.1±.204	15.0±0.192	50.6±0.272
Error of 1.....					±.499		
No. 407.....	134	67	66	56.0	58.2	15.1	50.8
No. 408.....	131	65	63	53.5	59.2	15.0	52.0
No. 409.....	131	65	64	54.0	58.8	15.6	51.1
Mean of 3.....					58.7±.161		
No. 410.....	128	67	66	56.0	56.3	15.1	48.5
No. 411.....	128	68	66	56.0	56.3	15.1	48.5
No. 412.....	128	66	64	54.0	57.8	15.6	50.0
Mean of 3.....					56.8±.275		
Mean of 6.....					57.8±.310	15.3±.070	50.2±.359
Error of 1.....					±.760		
No. 413.....	195	100	98	83.5	57.2	14.7	49.8
No. 414.....	192	97	95	81.5	57.6	14.1	50.6
No. 415.....	192	99	97	81.5	57.6	15.9	49.5
Mean of 3.....					57.5±.074		
No. 416.....	192	95	93	79.5	58.6	14.5	51.6
No. 417.....	192	96	95	80.0	58.4	15.7	51.6
No. 418.....	192	96	96	81.5	57.6	15.1	50.0
Mean of 3.....					58.2±.168		
Mean of 6.....					57.8±.137	15.0±.176	50.5±.230
Error of 1.....					±.335		
No. 419.....	256	128	126	107.0	58.2	15.1	50.8
No. 420.....	256	126	123	105.0	59.0	14.6	52.0
No. 421.....	256	130	127	108.5	57.7	14.6	50.4
Mean of 3.....					58.3±.208		
No. 422.....	256	126	125	105.0	59.0	16.0	51.2
No. 423.....	256	126	126	105.5	58.8	16.3	50.8
No. 424.....	256	130	129	109.0	57.5	15.5	49.7
Mean of 3.....					58.4±.260		
Mean of 6.....					58.4±.167	15.4±.179	50.8±.194
Error of 1.....					±.410		

SECTION H.—FIELD-CURED TIMOTHY COLLECTED AT NEW LONDON, OHIO.

[Dates of weighing: Original material, July 11; intermediate, Aug. 27; air-dry material, Sept. 28.]

No. 425.....	32	30	30	26.0	18.8	13.3	6.3
No. 426.....	32	30	30	26.0	18.8	13.3	6.3
No. 427.....	32	30	31	26.5	17.2	14.5	3.2
Mean of 3.....					18.3±0.294		
No. 428.....	32	30	30	25.5	20.4	15.0	6.3
No. 429.....	32	30	31	26.0	18.8	13.3	3.2
No. 430.....	32	29	30	26.0	18.8	13.3	6.3
Mean of 3.....					19.3±.294		
Mean of 6.....					18.8±.254	18.8±0.192	5.3±0.402
Error of 1.....					±.623		

TABLE I.—Comparison of different-sized samples of forage—Continued.

SECTION H.—FIELD-CURED TIMOTHY COLLECTED AT NEW LONDON, OHIO—Continued.

Sample.	Weight.				Moisture.		
	Original.	Intermediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
	Ounces.	Ounces.	Ounces.	Ounces.	Per cent.	Per cent.	Per cent.
No. 431.....	64	59	60	51.5	19.6	14.0	6.3
No. 432.....	64	59	59	51.5	19.6	12.7	7.9
No. 433.....	64	58	58	50.0	21.9	13.7	9.4
Mean of 3.....					20.4 ± .422		
No. 434.....	64	57	58	49.5	22.7	14.6	9.4
No. 435.....	64	58	60	51.0	20.3	15.0	6.3
No. 436.....	64	59	60	51.0	20.3	15.0	6.3
Mean of 3.....					21.1 ± .440		
Mean of 6.....					20.7 ± .321	14.2 ± .224	7.6 ± .384
Error of 1.....					± .786		
No. 437.....	96	87	88	75.5	21.4	14.1	8.4
No. 438.....	96	88	89	75.5	21.4	15.1	7.3
No. 439.....	96	89	88	75.5	21.4	14.1	8.4
Mean of 3.....					21.4 ± .000		
No. 440.....	96	88	88	76.0	20.8	13.6	8.4
No. 441.....	96	88	89	75.5	21.4	15.0	7.3
No. 442.....	96	85	85	73.0	24.0	14.1	11.5
Mean of 3.....					22.1 ± .541		
Mean of 6.....					21.7 ± .285	14.3 ± .148	8.6 ± .388
Error of 1.....					± .697		
No. 443.....	128	118	118	101.0	21.2	14.4	7.9
No. 444.....	128	118	117	101.0	21.2	13.7	8.6
No. 445.....	128	118	119	102.5	19.9	13.8	7.1
Mean of 3.....					20.8 ± .239		
No. 446.....	128	119	118	101.5	20.6	14.0	7.9
No. 447.....	128	121	122	104.0	18.8	14.7	4.7
No. 448.....	128	120	120	104.0	18.8	13.3	6.3
Mean of 3.....					19.4 ± .331		
Mean of 6.....					20.1 ± .277	14.0 ± .127	7.1 ± .354
Error of 1.....					± .678		

SECTION I.—GREEN RED AMBER SORGHUM COLLECTED AT AMARILLO, TEX.

[Dates of weighing: Original material, Sept. 4; intermediate, Dec. 5; air-dry material, Dec. 16.]

No. 201.....	64.0	32.0	25.0	16.5	74.2	34.0	60.9
No. 202.....	65.0	32.0	25.0	15.5	76.2	38.0	61.5
No. 203.....	70.0	35.0	28.0	19.0	72.9	32.1	60.0
Mean of 3.....					74.4 ± 0.528		
No. 204.....	64.0	34.0	27.0	16.5	74.2	38.9	57.8
No. 205.....	72.0	40.0	33.0	22.5	68.7	31.8	54.2
Mean of 3.....					71.9 ± .897		
Mean of 5.....					73.2 ± .516	34.8 ± 0.894	58.9 ± 0.801
Error of 1.....					± 1.153		
No. 206.....	137.0	73.0	65.0	39.0	71.5	40.0	52.6
No. 207.....	128.0	64.0	55.5	35.5	72.3	36.0	56.6
No. 208.....	136.0	76.0	66.0	40.0	70.6	39.3	51.5
Mean of 3.....					71.5 ± .270		
No. 209.....	139.0	72.0	64.0	41.0	70.5	35.9	54.0
No. 210 ¹							
Mean of 4.....					71.2 ± .248	37.9 ± .630	58.7 ± .643
Error of 1.....					± .494		
No. 211.....	204.0	110.0	100.5	61.0	70.1	39.3	50.7
No. 212.....	192.0	96.0	87.0	52.5	72.7	39.7	54.7
No. 213.....	200.0	110.0	100.0	61.0	69.5	39.5	50.0
Mean of 3.....					70.8 ± .541		

¹ Sample injured by mice.

TABLE I.—Comparison of different-sized samples of forage—Continued.

SECTION I.—GREEN RED AMBER SORGHUM COLLECTED AT AMARILLO, TEX.—Continued.

Sample.	Weight.				Moisture.		
	Original.	Inter-mediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
No. 214.....	Ounces. 196.0	Ounces. 106.0	Ounces. 97.5	Ounces. 62.5	Per cent. 68.1	Per cent. 35.9	Per cent. 50.3
No. 215.....	202.0	104.0	96.5	61.0	69.8	36.8	52.2
Mean of 3.....					69.1± .148		
Mean of 5.....					70.1± .451	38.1± .476	51.6± .523
Error of 1.....					±1.010		
No. 216.....	260.0	131.0	122.5	76.5	70.6	37.6	52.9
No. 217.....	258.0	131.0	122.0	78.0	69.8	36.1	52.7
No. 218.....	260.0	133.0	125.5	78.0	70.0	37.8	51.7
Mean of 3.....					70.1± .133		
No. 219.....	264.0	139.0	131.5	81.5	69.1	38.0	50.2
No. 220.....	262.0	129.0	119.0	74.0	71.8	37.8	54.6
Mean of 3.....					70.3± .437		
Mean of 5.....					70.3± .274	37.5± .209	52.4± .437
Error of 1.....					± .612		

SECTION J.—FIELD-CURED RED AMBER SORGHUM COLLECTED AT AMARILLO, TEX.

[Dates of weighing: Original material, Nov. 9; intermediate, Dec. 5; air-dry material, Dec. 16.]

No. 221.....	42	40.0	31.0	24.0	42.9	22.6	26.0
No. 222.....	35	33.0	24.0	17.0	51.4	31.4	31.4
No. 223.....	37	34.0	25.0	18.5	50.0	26.0	32.4
Mean of 3.....					48.1± 1.450		
No. 224.....	40	37.0	27.5	21.0	47.5	23.6	31.2
No. 225.....	38	35.0	26.0	19.0	50.0	26.9	31.6
Mean of 3.....					49.2± .459		
Mean of 5.....					48.4± .812	25.5± 0.712	30.5± 0.694
Error of 1.....					±1.816		
No. 226.....	67	61.0	52.5	35.5	47.0	32.4	21.6
No. 227.....	69	64.0	54.0	36.5	47.1	32.4	21.7
No. 228.....	70	64.0	54.5	38.5	45.0	29.4	22.1
Mean of 3.....					46.4± .377		
No. 229.....	70	64.0	54.0	38.0	45.7	29.6	22.9
No. 230.....	72	67.0	58.0	44.5	38.2	23.3	19.4
Mean of 3.....					43.0± 1.317		
Mean of 5.....					44.6± .987	29.3± 1.003	21.5± .351
Error of 1.....					±2.221		
No. 231.....	105	98.0	87.5	62.0	41.0	29.1	16.7
No. 232.....	104	96.0	85.5	62.5	40.0	26.9	17.8
No. 233.....	102	96.0	85.5	60.5	40.7	29.2	16.2
Mean of 3.....					40.6± .163		
No. 234.....	104	97.0	88.5	60.5	41.8	31.6	15.0
No. 235.....	106	100.0	88.0	60.5	42.9	31.3	17.0
Mean of 3.....					41.8± .349		
Mean of 5.....					41.3± .300	29.7± .515	16.5± .281
Error of 1.....					± .671		
No. 236.....	133	125.0	113.5	82.0	38.3	27.8	14.7
No. 237.....	135	127.0	116.0	79.5	41.1	31.5	14.1
No. 238.....	134	126.0	116.5	86.0	35.8	26.2	13.1
Mean of 3.....					38.4± .842		
No. 239.....	134	128.0	118.0	82.0	38.8	30.5	12.0
No. 240.....	134	124.0	115.0	84.0	37.3	27.0	14.2
Mean of 3.....					37.3± .477		
Mean of 5.....					38.3± .528	28.6± .617	13.6± .290
Error of 1.....					±1.182		

RELIABILITY OF AIR-DRIED SAMPLES.

The reliability of air-dried samples may be determined in three ways: (1) By a comparison of the percentages of moisture loss in the samples with that in the 100-pound and 500-pound quantities, which, on account of their bulk, approximate field methods; (2) by a careful comparison of the relation between the moisture lost in air drying and the total moisture content as revealed by oven drying; and (3) by noting the variation in the percentage of moisture remaining in the air-dried material. A comparison of the moisture loss in air-dried samples with that in bulk lots of the same material is given in Table II.

TABLE II.—*Comparison of the loss of moisture in green and field-cured forage when air dried in small samples and in large bulk.*

Place.	Crop.	Moisture in green material.			Moisture in field-cured material.		
		Total.	Loss in samples.	Loss in bulk.	Total.	Loss in samples.	Loss in bulk.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Chico, Cal.	Alfalfa	76.9	74.5	73.0	22.3	14.3	11.5
Arlington Farm, Va. . .	Tall oat-grass and orchard grass.	72.0	66.3	64.3	29.0	13.4	13.5
New London, Ohio . . .	Timothy	58.0	50.5	49.2	20.3	7.2	10.1
Amarillo, Tex.	Sorghum	71.2	54.2	58.2	43.2	20.5	16.8
Hays, Kans.	do.		65.8	60.9		26.0	22.1

It will be seen that the losses in the small samples of green material, except for those of sorghum at Amarillo, Tex., which were not well cured, averaged from 1.3 to 4.9 per cent greater than it did in the bulk lots. This was to be expected, since the small sample naturally dries out more completely than the bulk. The difference, however, is slight, and the loss of moisture in the small samples seems to be fairly consistent with the loss which was found in the bulk lots.

The comparison of small samples with bulk lots of field-cured material is not so favorable to the use of the sample method as in the case of the green material. Table II also shows that the moisture loss in the samples, when compared with the total moisture content, is not quite so consistent as the percentage of moisture loss in the bulk lots.

A better way to determine the reliability of the sample method is by a study of the percentages themselves, especially in the column devoted to percentage of moisture in the air-dry material. The uniformity of these percentages throughout one crop means that the air drying of samples can be depended upon to bring samples to a nearly uniform moisture content, and this method therefore serves the purpose of correcting field weights almost as well as to oven dry the samples. The moisture content of the air-dry samples is not en-

tirely uniform, but except in a few instances the probable error is quite low, averaging for over 200 samples only 0.28 of 1 per cent. With such a low probable error it seems entirely reasonable to depend upon the air drying of samples for all practical purposes.

COMPARISON OF SAMPLES OF GREEN FORAGE WITH SAMPLES OF FIELD-CURED FORAGE.

Summary Table III gives a complete comparison of the averages of the probable error in green and field-cured samples for the different crops as collected by six individuals. These averages include more than 250 samples of green material and more than 200 samples of field-cured material. The best index to the reliability of these samples is in the percentage of moisture in the original samples.

TABLE III.—Mean percentages of moisture in forage samples of different sizes, showing also probable errors.

SECTION A.—GREEN MATERIAL.¹

Sample.	Crop.	Place.	Moisture.		
			Original samples.	Air dry.	Lost in air drying.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4-pound.....	Sorghum..	Amarillo, Tex.	73.2±0.516	34.8±0.894	58.9±0.801
8-pound.....	do.....	do.....	71.2±.248	37.9±.630	53.7±.643
12-pound.....	do.....	do.....	70.1±.451	38.1±.476	51.6±.523
16-pound.....	do.....	do.....	70.3±.274	37.5±.209	52.4±.437
Mean.....			71.2	37.1	54.2
4-pound.....	Sorghum..	Hays, Kans..			66.9±.526
8-pound.....	do.....	do.....			68.0±.296
12-pound.....	do.....	do.....			64.9±.289
16-pound.....	do.....	do.....			63.4±.393
Mean.....					65.8
4-pound.....	Timothy..	New London, Ohio.	58.1±.204	15.0±.192	50.6±.272
8-pound.....	do.....	do.....	57.8±.310	15.3±.070	50.2±.359
12-pound.....	do.....	do.....	57.8±.137	15.0±.176	50.5±.230
16-pound.....	do.....	do.....	58.4±.167	15.4±.179	50.8±.194
Mean.....			58.0	15.2	50.5
4-pound.....	Tall oat-grass.	Arlington, Va.	71.1±.203	15.8±.095	65.9±.129
8-pound.....	do.....	do.....	71.5±.268	17.4±.145	65.5±.353
12-pound.....	do.....	do.....	72.2±.056	17.5±.157	66.3±.060
16-pound.....	do.....	do.....	73.3±.355	17.6±.079	67.5±.424
Mean.....			72.0	17.1	66.3
4-pound.....	Alfalfa....	Arlington, Va.	74.0±.344	10.7±.517	71.0±.237
8-pound.....	do.....	do.....	74.8±.225	10.5±.129	71.8±.257
12-pound.....	do.....	do.....	75.5±.160	10.9±.107	72.5±.136
16-pound.....	do.....	do.....	76.5±.155	10.8±.251	73.6±.155
Mean.....			75.2	10.7	72.2
4-pound.....	Alfalfa....	Chico, Cal....	75.1±.258	7.6±.253	73.0±.249
8-pound.....	do.....	do.....	76.7±.234	9.8±.407	74.2±.258
12-pound.....	do.....	do.....	77.7±.129	10.3±.113	75.2±.144
16-pound.....	do.....	do.....	78.0±.109	10.2±.098	75.4±.108
Mean.....			76.9	9.5	74.5

¹ A average probable error for the 4-pound samples, 0.305; for the 8-pound, 0.257; for the 12-pound, 0.187; for the 16-pound, 0.212; and for all the samples, 0.240.

TABLE III.—*Mean percentages of moisture in forage samples of different sizes, showing also probable errors—Continued.*SECTION B.—FIELD-CURED MATERIAL.¹

Sample.	Crop.	Place.	Moisture.		
			Original samples.	Air dry.	Lost in air drying.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
2-pound.....	Sorghum..	Amarillo, Tex.	48.4±0.812	25.5±0.712	30.5±0.694
4-pound.....	..do.....	..do.....	44.6±.987	29.3±1.003	21.5±.351
6-pound.....	..do.....	..do.....	41.3±.300	29.7±.515	16.5±.281
8-pound.....	..do.....	..do.....	38.3±.528	28.6±.617	13.6±.290
Mean.....			43.2	28.3	20.5
2-pound.....	Sorghum..	Hays, Kans.			26.9±.952
4-pound.....	..do.....	..do.....			25.0±.432
6-pound.....	..do.....	..do.....			26.9±.422
8-pound.....	..do.....	..do.....			25.0±.302
Mean.....					26.0
2-pound.....	Timothy..	New London, Ohio.	18.8±.254	13.8±.192	5.3±.402
4-pound.....	..do.....	..do.....	20.7±.321	14.2±.224	7.6±.384
6-pound.....	..do.....	..do.....	21.7±.285	14.3±.148	8.6±.388
8-pound.....	..do.....	..do.....	20.1±.277	14.0±.127	7.1±.354
Mean.....			20.3	14.1	7.2
2-pound.....	Tall oat-grass.	Arlington, Va.	31.8±.409	17.7±.295	17.1±.418
4-pound.....	..do.....	..do.....	29.2±.750	19.9±.861	14.1±.863
6-pound.....	..do.....	..do.....	27.8±.522	17.3±.112	12.7±.566
8-pound.....	..do.....	..do.....	27.2±.136	19.4±.113	9.5±.169
Mean.....			29.0	18.6	13.4
2-pound.....	Alfalfa....	Arlington, Va. ²	9.0±.193	9.5±.045	
4-pound.....	..do.....	..do.....	10.4±.099	10.0±.203	
6-pound.....	..do.....	..do.....	12.3±.257	9.4±.156	
8-pound.....	..do.....	..do.....	12.0±.181	11.0±.135	
Mean.....				10.0	
2-pound.....	Alfalfa....	Chico, Cal.	20.6±.558	8.6±.587	13.2±.611
4-pound.....	..do.....	..do.....	23.9±.585	9.7±.095	15.9±.548
6-pound.....	..do.....	..do.....	22.4±.399	9.3±.067	14.6±.452
8-pound.....	..do.....	..do.....	22.4±1.454	11.5±.186	13.4±.089
Mean.....			22.3	9.8	14.3

¹ Average probable error for the 2-pound samples, 0.445; for the 4-pound, 0.548; for the 6-pound, 0.353; for the 8-pound, 0.515; and for all the samples, 0.465.

² The alfalfa at Arlington was cured in the greenhouse before the original weight was taken, so that the original weight is of air-dry rather than of field-cured material.

The average probable error for the green samples is about 0.240 of 1 per cent, and of the field-cured samples 0.465 of 1 per cent. It appears from this that the probable error for green samples is approximately half that found in the corresponding field-cured samples. In field practice, however, this difference is not so important as it appears, because the bulk on which the correction is made in the field-cured material is approximately half of that where the original green weight is considered.

Much greater extremes, however, are found in the field-cured samples than in the green samples, showing that even though the average probable error is not excessive, still there is a possibility of sufficient error in these to affect the results when corrections are

made with only one sample. Table II also shows that the samples of field-cured material are less consistent than samples of green material when compared with bulk lots of the same forage dried under similar conditions.

RELATIVE VALUE OF SAMPLES OF DIFFERENT SIZES.

The figures on the relative value of samples of different sizes as given in Table III are not conclusive. There is a general, though not consistent, decrease in the probable error as the size of the sample is increased, but what would otherwise have been an expressive array of averages has been spoiled by the excessive probable error in the 8-pound field-cured sample of alfalfa at Chico, Cal. The average probable error for the 8-pound samples, including the Chico results, is 0.515 per cent; if we eliminate the Chico results it would be 0.281 per cent, which perhaps is nearer what might ordinarily be expected. It will be noted that as the green samples of alfalfa and of tall oat-grass increase in size, the greater was the percentage of loss in curing, as indicated by the column headed "Moisture in original samples" in Table III. This fact makes it seem probable that there was a loss, by fermentation, of matter other than water, but such a loss would not mean an increase of error in the use of samples when the samples are of a uniform size.

On account of the difficulty of curing samples of green forage they must necessarily be comparatively small, and when used in correcting actual field weights the samples, whether green or field cured, must be small enough to admit of easy handling. From the data presented in the table, it seems that the 4-pound field-cured and the 8-pound green samples are nearly as accurate as the larger ones. Considering accuracy, the facility of handling, the ease of figuring percentages, etc., 5-pound samples of field-cured and 10-pound samples of green material are recommended as the most desirable for practical work.

EFFECT OF REPLICATING THE SAMPLES.

The data on the effect of replicating the samples are found in Table IV, where the probable error has been expressed for single samples, replicates of three, and replicates of five and six.

TABLE IV.—Average of the probable errors of one, three, and five or six samples.*

Number of replications.	Field-cured material.					Green material.					Grand average.
	2-pound.	4-pound.	6-pound.	8-pound.	Average.	4-pound.	8-pound.	12-pound.	16-pound.	Average.	
One.....	<i>Per ct.</i> 1.006	<i>Per ct.</i> 1.243	<i>Per ct.</i> 0.818	<i>Per ct.</i> 0.994	<i>Per ct.</i> 1.015	<i>Per ct.</i> 0.686	<i>Per ct.</i> 0.586	<i>Per ct.</i> 0.407	<i>Per ct.</i> 0.486	<i>Per ct.</i> 0.527	<i>Per ct.</i> 0.777
Three.....	.458	.668	.397	.473	.499	.331	.277	.156	.256	.255	.377
Five and six.....	.445	.548	.353	.515	.465	.278	.257	.187	.212	.234	.349

Extreme care in sampling has kept the probable error very low on the single sample, so that it is nowhere excessive, but replicating the sample three times reduces the probable error 51.5 per cent, while a replication five and six times reduces the probable error over single samples 55.1 per cent and over three replications only 7.4 per cent. It does not seem necessary, therefore, in practice to replicate more than three times. Single samples, however, can not be considered safe when there is wide variation within the plat unless extreme care is used to make the sample composite and representative of the entire area.

MOISTURE PERCENTAGES IN GREEN FORAGE AND IN FIELD-CURED FORAGE, AS SHOWN BY SAMPLES.

Farrell, in an article in the *American Journal of Agronomy*,¹ suggests the desirability of expressing alfalfa-hay yields in terms of green weight. In the article referred to above, he reports 76.5 per cent of moisture lost in air drying, which would be approximately equivalent to 79.5 per cent of total moisture. The average percentage of moisture in the 23 analyses of green alfalfa reported by Jenkins and Winton² was 71.8.

At Arlington Farm, Va., green alfalfa averaged 75.2 per cent of moisture in 20 samples. This percentage is probably near the average for moderately thrifty alfalfa grown without irrigation in the Central and Eastern States. Alfalfa grown under irrigation and cut when one-tenth in bloom at Chico, Cal., averaged in 1914, 76.9 per cent of moisture. In 1911 McKee³ found at this station as the average of 28 determinations in alfalfa not quite in bloom 85.8 per cent of moisture. The 1914 results indicate that the condition of growth affects the moisture content very decidedly. Owing to excessive heat and scarcity of water, the alfalfa used for the 1914 samples was less vigorous than that of 1911 and correspondingly less succulent. These differences indicate very clearly the danger of basing yields on the green weight, as suggested by Farrell, or of using some arbitrary percentage of moisture in making corrections on the green weight. Samples should always be taken in experimental work when the crop is harvested and the amount of moisture in the forage at that time determined from them. Field-cured alfalfa at Chico in 1914 had 22.3 per cent of moisture, while Jenkins and Winton² report as the average of 21 analyses only 8.4 per cent. The samples of Jenkins and Winton had probably dried out to some extent after being brought into the laboratory.

¹ Farrell, F. D. Basing alfalfa yields on green weights. *In Jour. Amer. Soc. Agron.*, v. 6, no. 1, p. 42-45, 1914.

² Jenkins, E. H., and Winton, A. L. A compilation of analyses of American feeding stuffs. U. S. Dept. Agr., Office Exp. Stas. Bul. 11, p. 22-75, 1892.

³ McKee, Roland. Arabian alfalfa. *In U. S. Dept. Agr., Bur. Plant Indus. Cir.* 119, p. 25-30, 1913.

The bulk of the timothy samples taken at New London, Ohio, in 1914 were overmature for hay, being past bloom and with many of the lower leaves dead. In this condition the green timothy contained only 58 per cent of moisture, but when cut at the proper time (in bloom) it contained 71.4 per cent. The timothy which contained 58 per cent of moisture when green contained 20.3 per cent when field cured. Jenkins and Winton¹ report an average of 61.6 per cent of moisture for green timothy and 13.2 per cent for field cured.

Meadow hay at Arlington Farm, Va., containing a mixture of tall oat-grass and orchard grass had when green 72 per cent and when field cured 29 per cent of moisture. Although the field-cured samples were taken after the hay had dried sufficiently so that moisture could not be wrung from the stems by twisting a bunch of hay in the hands, still it was adjudged not quite dry enough to stack.

Red Amber sorghum in fairly thrifty condition at Amarillo, Tex., had 71.2 per cent of moisture when green and 43.2 per cent when field cured. The percentage of moisture, though about the same as that of other crops for the green material, was much higher in the field-cured state. Undoubtedly this was due to the moisture carried in the stems. Jenkins and Winton¹ report 79.4 per cent of moisture in green sorghum, but give no figures for the field-cured material. In corn, however, which should be much the same as sorghum, the average of 126 analyses of green material showed 79.3 per cent of moisture, while 35 analyses of field-cured material gave an average of 42.2 per cent of moisture.

These results go to show that forage crops when ready to harvest average about 70 to 80 per cent of moisture in the fresh material. Field-cured material of different crops varies so widely in moisture content that the percentage to be expected in any one case can hardly be foretold.

MOISTURE LOST IN AIR DRYING SAMPLES.

Consideration of the means in Table III shows that irrigated alfalfa at Chico, Cal., lost in air drying 74.5 per cent of moisture out of a total of 76.9 per cent. Unirrigated alfalfa at Arlington Farm, Va., lost 72.2 per cent out of a total of 75.2 per cent. Timothy at New London, Ohio, lost 50.5 per cent out of a total moisture content of 58 per cent, but, as shown in Table VI, the loss was 68.8 per cent when the total moisture content was 71.4 per cent; the mixture of tall oat-grass and orchard grass at Arlington Farm, Va., lost 66.3 per cent out of a total of 72 per cent; and the Red Amber sorghum at Amarillo lost 54.2 per cent out of a total of 71.2 per cent. At Hays, Kans., sorghum lost 65.8 per cent in air drying. This difference is no doubt due to the fact that the stems of the sorghum

¹ Jenkins, E. H., and Winton, A. L. Op. cit.

were split in the Hays samples, while in the Amarillo samples the stems were left entire. Splitting the stems when collecting sorghum samples greatly accelerates air drying and probably adds to the uniformity of the dried samples. This practice is recommended in the preparation of sorghum samples for correcting yields.

AMOUNT OF MOISTURE IN AIR-DRY SAMPLES.

The amount of moisture in the air-dry material depends not only upon the humidity of the atmosphere but also on the nature of the material in the sample. The sorghums, unless allowed to remain an extraordinary time under conditions suited for drying, retain a considerable percentage of moisture because of their large stems with the hard outer walls. Alfalfa, on the other hand, being quite succulent and leafy, loses its moisture rapidly and rather completely. Alfalfa at Chico had 9.7 per cent of moisture in the air-dried material, while at Arlington Farm, Va., there was 10.4 per cent. This difference probably represents the effect of the different degrees of humidity at the two places.

Timothy at New London, Ohio, retained 14.7 per cent of moisture in the air-dried material, while the mixture of tall oat-grass and orchard grass at Arlington Farm, Va., retained 17.9 per cent. Sorghum at Amarillo, where the stems were not split in the samples, retained an average of 32.7 per cent. It is unfortunate that dry-matter determinations were not made on the samples collected at Hays, Kans., as this would have given an opportunity to compare with the Amarillo samples others in which the stems were split and the drying was much more complete.

The above percentages no doubt represent fairly accurately the moisture percentages which may be expected in the air-dry samples of these different crops.

EFFECTS OF DRYING SAMPLES IN THE SUN AND IN THE SHADE.

To compare the relative moisture content of air-dry material allowed to cure in the shade with that cured in the direct sunshine, two sets of alfalfa samples were taken at Chico, Cal., and two sets of the mixture of tall oat-grass and orchard grass were prepared at Arlington Farm, Va., one set at each station being placed in the shade to cure, while the corresponding set was cured in the sun. The results, as given in Table V, show that while the total shrinkage was greater in the shade-cured samples at both places the moisture content of the air-dry material was a little less in the sun-cured samples at Chico and a little greater in those cured in the same way at Arlington Farm.

TABLE V.—*Comparison of sun-dried and shade-dried samples of green material of alfalfa and of a mixture of tall oat-grass and orchard grass.*

Place.	Crop.	Treatment.	Moisture, original material.	Moisture, air-dry material.	Moisture lost in air drying.
Arlington Farm, Va....	Tall oat-grass and orchard grass.	Cured in shade..	<i>Per cent.</i> 71.5±0.268	<i>Per cent.</i> 17.4±0.145	<i>Per cent.</i> 65.5±0.353
Do.....	do.....	Cured in sun....	70.8±.391	19.8±.204	63.5±.558
Chico, Cal. ¹	Alfalfa.....	Cured in shade..	75.9±.267	11.6±.486	72.7±.314
Do. ¹	do.....	Cured in sun....	74.0±.061	10.7±.180	70.8±.120

¹ The detailed record of these samples is given in Table XII. Samples 549, 550, 551, 554, 555, 556, and 557 were cured in the shade; Nos. 552, 553, 559, and 560 were cured in the sun.

The differences indicated in Table V are too small to warrant any conclusions, even if the results at the two stations agreed. It would seem, therefore, that so far as the moisture content of the air-dry material is concerned it makes little difference whether the samples are dried in the sun or in the shade. The greater shrinkage in the shade-dried samples was perhaps due to loss of dry material on account of fermentation, which might well be greater in green material dried in the shade than that dried in the sun on account of the more favorable conditions for the development of fermentation organisms.

VALUE OF CORRECTING FIELD WEIGHTS BY THE SAMPLE METHOD.

The work so far done in correcting forage yields by samples makes it apparent that the method is of greatest importance with crops that lose their moisture slowly, such as the sorghums and Sudan grass. It is also valuable in comparative work where the treatment accorded different plats of the same crop differs widely, or in a comparison of varieties that lose moisture at different rates. The use of this method of correcting yields by samples, if it should become general, would be of much value in standardizing agronomic data obtained in different countries and different parts of the United States, where conditions affecting a crop during the growing and harvesting period differ greatly.

The use of the sample method and the differences which may be expected from corrections made in this way are well illustrated by the following results obtained on the forage-crop field stations in the regular plat work.

Sorghum.—At Chico, Cal., the corrected weight of sorghum, as determined by the use of air-dried samples, was 41.6 to 47 per cent less than the weights taken in the field at the time of stacking the crop. This fodder was not as dry at the time of taking the field weights as is desirable, yet it may fairly have been called field cured in the ordinary meaning of the term. At Hays, Kans., the corrected weights, as computed from air-dried samples, average 20 to 30 per cent

lower than the field weights, even when the sorghum had been curing through seven weeks of good drying weather after harvest. The differences in field-cured and computed air-dry weights for different varieties and different dates of planting varied from minus 3.7 per cent to plus 31.3 per cent. It would seem, therefore, that maturity at harvest, size of shock, and succulence of the variety are factors affecting the moisture content of field-cured sorghum almost as much as different lengths of drying periods. At Amarillo, Tex., the difference in the percentage of moisture in field-cured material of Red Amber sorghum and air-dry samples of the same varied from 12 to 33 per cent, while the total moisture in the samples varied from 35.8 to 55.7 per cent, as determined by oven drying. Such differences are enough in many instances to change the conclusions of the value of different methods of treatment or different dates of planting.

Sudan grass.—At Hays, Kans., after Sudan grass had been cured three days, the field weights were 25 to 40 per cent greater than the computed air-dry weights based on samples, and there was 21 to 40 per cent difference after a similar period of curing at Chillicothe, Tex. Many of the phenomenal yields of Sudan grass and sorghum that are reported by newspapers can be explained in part by this excessive moisture content.

Alfalfa.—The computed air-dry weights of alfalfa at Chico, Cal., were 10 to 15 per cent less than the field-cured weights, while at Hays, Kans., in good curing weather, there was a difference of only 2 per cent.

Different methods of culture affect the moisture content quite decidedly, as shown with alfalfa at Chico, where in the May 15 cutting the hay from drilled plats showed only 10.9 per cent loss in air drying, while in the 35-inch rows the loss was 24.3 per cent. Cuttings of alfalfa made at different stages of maturity can not be compared accurately unless they are checked by the sample method. The difference in moisture content of the field-cured material has been found in a number of instances to be as great as 30 per cent.

Millet.—Of all the crops tested, millet showed the least difference between the air-dried and the field-cured material. The loss at Hays, Kans., averaged about 9.3 per cent.

RELATION OF THE STAGE OF GROWTH OF FORAGE PLANTS TO THEIR MOISTURE CONTENT.

It has long been known that plants when young contain a larger percentage of water than they do when mature, but no great amount of data on this point, even for our principal crop plants, is to be found. A compilation¹ of all the data available on this subject indicates the average percentage of moisture in alfalfa to be as follows:

¹ Vinall, H. N., and McKee, Roland. A digest of literature relating to the moisture content and shrinkage of forage. *In Jour. Amer. Soc. Agron.*, v. 8, no. 2, 1916.

Height of 18 inches, 83.3; in bud, 79.1; early bloom, 77.8; half in bloom, 74.3; in full bloom, 70.6; bloom fading, 68.3; leaves drying, 65.1; fully ripe, 55.9. For timothy: Heads not yet visible, 74.4; heads just appearing, 72.9; heads fully out, 70.8; beginning to bloom, 66.7; in full bloom, 64.3; past bloom, 59.8; seed fully formed, 54.3; seed becoming hard, 49.2.

Investigations on this point were made with the following crops: At Chico, Cal., alfalfa; at Hays, Kans., and Amarillo, Tex., sorghum; and at New London, Ohio, timothy. In the alfalfa several cuttings were made at intervals early in the season, so that later all the different stages of maturity could be secured on the same date. The same result was accomplished in the annuals by using plats of sorghum which were planted at different dates. The intention was to handle the timothy in the same way as the alfalfa, but such arrangements were found impossible, and the cuttings of timothy were made on different dates. Samples of all these crops were secured, representing approximately the following stages of development:

- (a) Very young, intermediate between the beginning of growth and budding.
- (b) In bud, before bloom began.
- (c) About one-tenth in bloom.
- (d) Full bloom.
- (e) Fully mature, seed hardening.

Eight-pound samples representing each stage of development were taken immediately after cutting. Each sample was placed in a sack and kept for 20 days or more until it became perfectly air dry. The amount of moisture lost in air drying was then determined and the sample was sent to Washington, D. C., where it was reduced to a water-free basis in the drying oven. The results obtained with the different crops are given in Table VI, the averages for each crop being also set forth in a separate summary (Table VII).

TABLE VI.—*Moisture in growing forage at different stages of development and in the air-dry material.*

SECTION A.—ALFALFA SAMPLES COLLECTED AT CHICO, CAL.

[Dates of weighing: Original material, July 2; intermediate, Aug. 19; air-dry material, Aug. 24.]

Sample and stage of growth.	Weight.				Moisture.		
	Green.	Inter-mediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
Very young; 12 inches high:	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 586.....	123.2	27.95	27.95	24.0	80.5	14.1	77.3
No. 587.....	123.2	29.45	29.45	26.0	79.0	11.8	76.1
No. 588.....	123.2	31.70	31.95	28.0	77.3	12.3	74.1
No. 589.....	123.2	31.45	31.45	28.0	77.3	11.1	74.5
No. 590.....	123.2	27.95	28.20	24.5	80.2	13.1	77.1
Average.....					78.9±0.412	12.5±0.314	75.8±0.395

TABLE VI.—*Moisture in growing forage at different stages of development, etc.—Cont'd.*

SECTION A.—ALFALFA SAMPLES COLLECTED AT CHICO, CAL.—Continued.

Sample and stage of growth.	Weight.				Moisture.		
	Green.	Inter-mediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
One-tenth bloom:	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 581.....	123.2	30.95	30.95	26.0	78.9	16.0	74.9
No. 582.....	123.2	32.20	31.95	28.5	76.9	10.7	74.2
No. 583.....	123.2	30.95	30.95	27.5	77.7	11.1	74.9
No. 584.....	123.2	34.70	34.20	31.0	74.8	9.2	72.3
No. 585.....	123.2	31.95	31.70	28.0	77.3	11.6	74.3
Average.....					77.1±.393	11.7±.689	74.1±.289
Full bloom:							
No. 576.....	123.2	35.45	35.20	31.5	74.4	10.5	71.5
No. 577.....	123.2	35.45	35.45	31.5	74.4	11.2	71.2
No. 578.....	123.2	35.20	34.95	31.0	74.8	11.2	71.6
No. 579.....	123.2	34.70	34.95	31.0	74.8	11.2	71.6
No. 580.....	123.2	35.45	35.20	31.0	74.8	11.8	71.5
Average.....					74.6±.060	11.2±.124	71.5±.045
Past full bloom:							
No. 571.....	123.2	38.20	37.95	33.5	72.8	11.7	69.2
No. 572.....	123.2	37.45	36.95	33.0	73.2	10.6	70.0
No. 573.....	123.2	35.95	35.70	31.5	74.5	11.8	71.0
No. 574.....	123.2	36.70	36.70	32.5	73.7	11.5	70.2
No. 575.....	123.2	37.95	37.70	33.5	72.9	11.2	69.5
Average.....					73.4±.188	11.4±.131	70.0±.188

SECTION B.—SORGHUM SAMPLES COLLECTED AT AMARILLO, TEX.

[Dates of weighing: Original material, Aug. 17; intermediate, Nov. 2; air-dry material, Dec. 17.]

Very young:							
No. 241.....	135	25	15.5	13.0	90.4	16.1	88.5
No. 242.....	136	30	15.0	11.5	91.5	23.3	89.0
No. 243.....	134	25	15.0	13.0	90.3	13.3	88.8
No. 244.....	138	23	15.0	13.0	90.6	13.3	89.1
No. 245.....	135	24	15.0	13.0	90.4	13.3	88.9
Average.....					90.6±0.134	15.9±1.169	88.9±0.063
Heads in boot:							
No. 246.....	139	40	27.0	19.0	86.3	29.6	80.6
No. 247.....	138	39	24.0	18.0	87.0	25.0	82.6
No. 248.....	138	36	22.0	17.0	87.7	22.7	84.1
No. 249.....	140	39	25.0	18.0	87.1	28.0	82.1
No. 250.....	140	38	24.0	17.5	87.5	27.1	82.9
Average.....					87.1±.146	26.5±.725	82.5±.347
Beginning to head:							
No. 251.....	135	40	28.0	20.0	85.2	28.6	79.3
No. 252.....	113	42	29.0	21.5	84.0	25.9	78.4
No. 253.....	134	39	27.0	21.0	84.9	22.2	80.6
No. 254.....	389	41	29.0	21.0	84.8	27.6	79.0
No. 255.....	140	40	28.0	21.0	85.0	25.0	80.0
Average.....					84.8±.124	25.9±.670	79.5±.232
Heads in bloom:							
No. 256.....	138	48	34.5	26.0	81.2	24.6	75.0
No. 257.....	138	48	35.0	26.0	81.2	25.7	74.6
No. 258.....	138	49	35.5	28.0	79.7	21.1	74.3
No. 259.....	139	47	34.5	27.5	80.2	20.3	75.2
No. 260.....	138	47	35.5	28.0	79.7	21.1	74.3
Average.....					80.4±.204	22.6±.652	74.7±.111
Ripe:							
No. 261.....	132	58	43.5	34.0	74.3	21.8	67.0
No. 262.....	136	59	45.5	33.0	75.7	27.5	66.5
No. 263.....	135	59	44.0	33.0	75.6	25.0	67.4
No. 264.....	135	58	42.5	33.0	75.6	22.4	68.5
No. 265.....	141	62	46.0	35.0	75.2	23.9	67.4
Average.....					75.3±.157	24.1±.612	67.4±.199

TABLE VI.—*Moisture in growing forage at different stages of development, etc.*—Cont'd.

SECTION C.—SORGHUM SAMPLES COLLECTED AT HAYS, KANS.

[Dates of weighing: Original material, Aug. 18; intermediate, Sept. 21; air-dry material, Sept. 27.]

Sample and stage of growth.	Weight.				Moisture.		
	Green.	Inter-mediate.	Air dry.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
Very young:	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 301.....	154.00	23.00	18.50	15.25	91.0	17.5	88.0
No. 302.....	159.50	27.50	20.50	17.25	89.2	15.8	87.1
No. 303.....	141.25	24.25	20.75	17.75	87.4	14.4	85.3
No. 304.....	150.00	23.00	19.00	16.25	89.3	15.0	87.3
No. 305.....	147.50	23.50	19.00	16.25	89.0	14.4	87.1
Average.....					89.2 ± 0.344	15.4 ± 0.349	87.0 ± 0.270
Bloom:							
No. 306.....	146.75	31.75	25.75	21.50	85.3	16.5	82.6
No. 307.....	134.25	29.25	24.75	20.75	84.5	16.0	81.6
No. 308.....	143.75	30.75	26.25	23.25	83.8	11.5	81.7
No. 309.....	150.25	34.25	27.75	23.25	85.0	16.1	81.6
No. 310.....	157.50	33.50	30.50	25.50	83.8	16.3	80.6
Average.....					84.5 ± .185	15.3 ± .572	81.6 ± .192
Soft dough:							
No. 311.....	150.25	38.25	28.75	24.75	83.5	13.8	80.9
No. 312.....	140.50	37.00	31.50	26.50	81.4	16.0	77.6
No. 313.....	157.50	37.50	34.50	29.25	81.4	15.1	78.1
No. 314.....	151.75	39.75	35.75	30.00	80.2	16.0	76.4
No. 315.....	160.75	45.75	40.25	33.50	79.2	16.7	75.0
Average.....					81.1 ± .434	15.5 ± .302	77.6 ± .593
Hard dough:							
No. 316.....	159.75	46.75	41.25	34.00	78.7	17.5	74.2
No. 317.....	166.75	57.75	38.25	32.75	81.4	14.4	77.1
No. 318.....	131.75	42.75	40.25	33.50	74.6	16.7	69.4
No. 319.....	149.75	46.75	43.75	36.50	75.6	16.5	70.8
No. 320.....	160.50	49.50	45.50	38.50	76.0	15.4	71.6
Average.....					77.3 ± .746	16.1 ± .326	72.6 ± .823
Seed ripe:							
No. 321.....	151.00	54.00	42.2	36.75	75.7	13.0	72.1
No. 322.....	149.25	53.25	41.75	34.75	76.7	16.8	72.0
No. 323.....	139.25	50.25	48.75	39.75	71.5	18.5	65.0
No. 324.....	157.00	61.00	56.5	47.75	69.6	15.5	64.0
No. 325.....	141.50	49.50	46.5	38.75	72.6	16.7	67.1
Average.....					73.2 ± .795	16.1 ± .549	68.0 ± 1.033

SECTION D.—TIMOTHY SAMPLES COLLECTED AT NEW LONDON, OHIO.

[Dates of weighing: Original material, May 20 to July 20; intermediate, Sept. 2; air-dry material, Sept. 28.]

Very young, May 20, 10-12 inches high:							
No. 449.....	124		31	28.0	77.5	9.6	75.0
Just heading:							
No. 450.....	138	37	35	32.5	76.5	7.1	74.6
No. 451.....	158	42	41	37.0	76.6	9.7	74.0
Average.....					76.6 ± 0.034	8.4 ± 0.620	74.3 ± 0.143
Early bloom, June 20:							
No. 452.....	137	44	43	39.0	71.6	9.3	68.6
No. 453.....	135	43	42	39.0	71.2	7.1	68.9
Average.....					71.4 ± .095	8.2 ± .525	68.8 ± .076
Full bloom, June 26:							
No. 454.....	131	47	46	42.0	68.0	8.7	64.9
No. 455.....	132	51	49	44.5	66.3	9.1	62.9
Average.....					67.2 ± .406	8.9 ± .095	63.9 ± .337
Leaves drying, July 7:							
No. 456.....	119	56	54	48.5	59.3	10.1	54.5
No. 457.....	127	62	60	53.5	57.9	10.8	52.8
Average.....					58.6 ± .334	10.5 ± .169	53.7 ± .406
Seed mature, July 20:							
No. 458.....	131	75	70	64.0	51.2	8.5	46.6
No. 459.....	131	74	71	64.0	51.2	9.8	45.8
Average.....					51.2 ± .000	9.2 ± .311	46.2 ± .191

These results, which agree fairly well with the averages for timothy and alfalfa cited on page 23, show a decided decrease in moisture percentage as the crop approaches maturity. This difference is least in alfalfa and greatest in timothy, although in sorghum it was also considerable. The exact relation of the three crops as regards the moisture content at different periods of their growth is not apparent, because the stage of maturity when samples were taken was not identical in the three crops. It is quite probable that the mature seed stage of timothy, when the moisture content reached the very lowest figure, 51.2 per cent, was relatively later in the life period of the crop than was the ripe stage in the sorghums. This may account partly for the rather decided difference in the amount of moisture contained by the two crops at this stage. It appears, however, that sorghum has an unusually high moisture content throughout its entire life period. The fact that the very young sorghum plant is approximately 90 per cent water, while the young timothy is only 77 per cent and the young alfalfa 79 per cent water, suggests one reason why cutting sorghum when it is very immature affects the feeding value of the resulting hay so much more seriously than a like treatment does timothy or alfalfa.

These results are more apparent in the summary (Table VII), where the averages are brought together so as to make comparisons easier.

TABLE VII.—*Summary of average percentages of moisture in sorghum, timothy, and alfalfa at different stages of growth.*

Place, crop, and stage of growth.	Moisture.		
	Original material.	Air-dry material.	Lost in air drying.
Amarillo, Tex., Red Amber sorghum:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Very young	90.6±0.134	15.9±1.169	88.9±0.063
Shooting for heads.....	87.1±.146	20.5±.725	82.5±.347
Beginning to head.....	84.8±.124	25.9±.670	79.5±.232
Full bloom.....	80.4±.204	22.6±.652	74.7±.111
Ripe.....	75.3±.157	24.1±.612	67.4±.199
Hays, Kans., Red Amber sorghum:			
Very young	89.2±.344	15.4±.349	87.0±.270
Bloom.....	84.5±.185	15.3±.572	81.6±.192
Soft dough.....	81.1±.434	15.5±.302	77.6±.593
Hard dough.....	77.3±.746	16.1±.326	72.6±.823
Ripe.....	73.2±.795	16.1±.549	68.0±1.033
New London, Ohio, timothy: ¹			
May 20.....	77.5	9.6	75.0
Very young, 12 inches high, June 8.....	76.6±.034	8.4±.620	74.3±.143
Early bloom, June 20.....	71.4±.095	8.2±.525	68.8±.076
Full bloom, June 26.....	67.2±.406	8.9±.095	63.9±.337
Leaves drying, July 7.....	58.6±.334	10.5±.165	53.7±.406
Seed mature, July 20.....	51.2±.000	9.2±.311	46.2±.191
Chico, Cal., alfalfa:			
Plants 12 inches high.....	78.9±.412	12.5±.314	75.8±.395
First bloom to one-tenth in bloom.....	77.1±.393	11.7±.689	74.1±.289
Full bloom.....	74.6±.060	11.2±.124	71.5±.045
Past full bloom.....	73.4±.188	11.4±.131	70.0±.188

¹ Only 1 sample taken on May 20; on other dates 2 samples were taken.

The effect of the stage of development on the amount of moisture remaining in the air-dry material, as shown in Table VII, is also a matter of interest. In the case of alfalfa at Chico, Cal., the young plants air dry contained a little more moisture than the older plants. At New London, Ohio, timothy showed practically no difference. Red Amber sorghum at Hays, Kans., showed no difference, while at Amarillo, Tex., the young plants contained decidedly less. The uniformity of the moisture content at Hays and the lack of uniformity at Amarillo (Table VI) is accounted for by the fact that at Hays the stems of each sample were split, thus allowing the complete drying of the mature samples, while at Amarillo the stems were not split, and the immature specimens dried out more completely than the mature ones.

LOSS OF MOISTURE IN FORAGE DURING THE EARLY STAGES OF CURING.

To determine the rate of loss of moisture in different crops during the period directly following the cutting in different localities and under different weather conditions, the following crops were used: At Arlington Farm, Va., alfalfa and a mixture of tall oat-grass and orchard grass; at Chico, Cal., alfalfa; at New London, Ohio, timothy; and at Hays, Kans., sorghum. The material was cut as quickly as possible and weighed immediately, using about 100 pounds green weight. This 100 pounds of green forage was placed on a canvas and weighed every 10 minutes through 1 hour, and every 30 minutes thereafter until 4 hours had elapsed. At Hays and New London determinations were made under both clear and partly cloudy conditions, but at Chico and Arlington Farm determinations were made for each crop under one condition only.

At Hays, Kans., the experiment was carried out with Red Amber sorghum in the soft-dough stage, and records of moisture loss were secured both for forage scattered as it would be in the swath, and also bunched, as it would be if raked into windrows. On August 18 the sky was partly cloudy, the wind was blowing but little, and the maximum temperature was 104° F. On September 25 the first weights were taken at 1.40 p. m., and the last at 5.40 p. m. The day was bright, with a gentle breeze and a maximum temperature of 82° F. Table VIII gives the rate of loss of moisture in these experiments.

The rate of loss was greatest in the scattered material, but the difference is not as great as one might expect. In the first 30 minutes the loss ranged from 1 to 2 per cent. The difference in the amount of moisture lost by the bunched and the scattered lots was 4.89 per cent on August 18 and 4 per cent on September 25. The greatest loss in 4 hours in the bunched lots was 8.2 per cent and in the scattered lots 13.1 per cent.

TABLE VIII.—Rate of loss of moisture in Red Amber sorghum during the early stages of curing at Hays, Kans., in 1914.

Time of weighing.	Time elapsed.	On August 18.				On September 25.			
		Bunched.		Scattered.		Bunched.		Scattered.	
		Weight.	Loss in weight.	Weight.	Loss in weight.	Weight.	Loss in weight.	Weight.	Loss in weight.
	Hr. m.	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.	Pounds.	Per cent.
1.45 p. m.	...	110.0	0	99.5	0	100.0	0	100.0	0
1.55 p. m.	10	109.5	.5	99.0	.5	99.5	.5	100.0	0
2.05 p. m.	20	109.0	.9	98.0	1.5	99.0	1.0	99.5	.5
2.15 p. m.	30	108.0	1.8	97.5	2.0	98.5	1.5	99.0	1.0
2.25 p. m.	40	107.5	2.3	97.0	2.5	98.5	1.5	98.0	2.0
2.35 p. m.	50	106.5	3.2	95.5	4.0	96.0	4.0	97.5	2.5
2.45 p. m.	1	106.0	3.6	94.5	5.0	97.5	2.5	97.0	3.0
3.15 p. m.	1 30	104.5	5.0	93.5	6.0	97.0	3.0	96.0	4.0
3.45 p. m.	2	104.0	5.5	90.5	9.0	96.5	3.5	95.0	5.0
4.15 p. m.	2 30	103.0	6.4	89.0	10.6	96.5	3.5	94.0	6.0
4.45 p. m.	3	102.5	6.8	88.0	11.6	95.5	4.5	93.0	7.0
5.15 p. m.	3 30	102.0	7.3	87.0	12.6	95.5	4.5	92.0	8.0
5.45 p. m.	4	101.0	8.2	86.5	13.1	95.0	5.0	91.0	9.0

The striking point to be noted in connection with Table VIII is the great difference in the rate of moisture loss between sorghum and alfalfa or timothy, as indicated in Tables VIII to XI, inclusive.

At New London, Ohio, determinations were made of the rate of loss of moisture in timothy cut when in full bloom on July 4 and again on July 6. The sky was partly cloudy on July 4 and the temperature was 76° F. at noon. On July 6 the sky was clear and the thermometer registered 80° F. at 11 o'clock a. m., 79° at 1 o'clock p. m., and 76° at 4 o'clock p. m. In each case the samples were scattered in drying.

TABLE IX.—Rate of loss of moisture in timothy during the early stages of curing at New London, Ohio, in 1914.

Time of weighing.	Time elapsed.	Weight.	Loss in weight.	Time of weighing.	Time elapsed.	Weight.	Loss in weight.
	Hr. m.	Pounds.	Per cent.		Hr. m.	Pounds.	Per cent.
July 4:				July 6:			
12.00 m.	...	115	0	11.00 a. m.	...	115	0
12.10 p. m.	10	112	2.6	11.10 a. m.	10	112	2.6
12.20 p. m.	20	110	4.3	11.20 a. m.	20	110	4.3
12.30 p. m.	30	107	7.0	11.30 a. m.	30	108	6.1
12.40 p. m.	40	106	7.8	11.40 a. m.	40	106	7.8
12.50 p. m.	50	105	8.7	11.50 a. m.	50	104	9.6
1.00 p. m.	1	103	10.4	12.00 m.	1	103	10.4
1.30 p. m.	1 30	99	13.9	12.30 p. m.	1 30	98	14.8
2.00 p. m.	2	96	16.5	1.00 p. m.	2	94	18.3
2.30 p. m.	2 30	92	20.0	1.30 p. m.	2 30	89	22.6
3.00 p. m.	3	88	23.5	2.00 p. m.	3	86	25.2
3.30 p. m.	3 30	85	26.1	2.30 p. m.	3 30	84	27.0
4.00 p. m.	4	83	27.9	3.00 p. m.	4	81	29.6
4.30 p. m.	4 30	80	30.4	3.30 p. m.	4 30	78	32.2
5.00 p. m.	5	80	30.4	4.00 p. m.	5	77	33.0

The data given in Table IX show that in the first 30 minutes after cutting on July 4 there was a loss of 7 per cent and on July 6 in the same time a loss of 6.1 per cent. In the first hour on both dates the loss was 10.4 per cent, and in 5 hours the loss was 30.4 per cent on

July 4 and 33 per cent on July 6. These results show the rate of moisture loss in timothy at New London, Ohio, to be very nearly the same as that of alfalfa and the mixture of tall oat-grass and orchard grass at Arlington Farm, Va. (Table X), where the atmospheric humidity and the temperatures are very similar to those at New London.

Determinations of the rate of loss of moisture in a mixture of tall oat-grass and orchard grass and in alfalfa during the early stages of curing were made at Arlington Farm, Va., on June 3 and on October 16, 1914, respectively. The data secured in this work are given in Table X.

TABLE X.—Rate of loss of moisture in a mixture of tall oat-grass and orchard grass and in alfalfa during the early stages of curing at Arlington Farm, Va., in 1914.

Tall oat-grass and orchard grass.				Alfalfa.			
Time of weighing.	Time elapsed.	Weight.	Loss in weight.	Time of weighing.	Time elapsed.	Weight.	Loss in weight.
June 3:	<i>Hr. m.</i>	<i>Pounds.</i>	<i>Per cent.</i>	Oct. 16:	<i>Hr. m.</i>	<i>Pounds.</i>	<i>Per cent.</i>
12.30 p. m.	--	100.0	0	12.40 p. m.	--	100.0	0
12.45 p. m.	-- 15	96.5	3.5	12.50 p. m.	-- 10	98.0	2.0
12.55 p. m.	-- 25	95.0	5.0	1.00 p. m.	-- 20	96.0	4.0
1.10 p. m.	-- 40	92.5	7.5	1.10 p. m.	-- 30	94.0	6.0
1.20 p. m.	-- 50	90.0	10.0	1.20 p. m.	-- 40	91.0	9.0
1.30 p. m.	1 --	88.5	11.5	1.30 p. m.	-- 50	89.0	11.0
1.45 p. m.	1 15	86.0	14.0	1.40 p. m.	1 --	86.0	14.0
2.15 p. m.	1 45	80.5	19.5	2.10 p. m.	1 30	81.0	19.0
2.45 p. m.	2 15	76.5	23.5	2.40 p. m.	2 --	77.0	23.0
3.15 p. m.	2 45	73.0	27.0	3.20 p. m.	2 40	75.0	25.0
3.45 p. m.	3 15	70.0	30.0	3.40 p. m.	3 --	72.5	27.5
4.15 p. m.	3 45	66.5	33.5	4.10 p. m.	3 30	69.5	30.5
				4.40 p. m.	4 --	68.0	32.0

The afternoon of June 3 was bright and fairly free from cloudiness, with a maximum temperature of 82° F. Under these conditions the mixture of tall oat-grass and orchard grass which was scattered on a tarpaulin lost 5 per cent of its weight in the first 25 minutes, 11.5 per cent in 1 hour, and 33.5 per cent in 3 hours and 45 minutes after cutting. The weights were taken as quickly as possible and the material scattered each time as soon as the tarpaulin was lowered. It will be noted that the loss of moisture was quite rapid, exceeding slightly that of the timothy at New London, Ohio.

The afternoon of October 16 was partly cloudy, but very warm for that season, the maximum temperature for the day being 73° F. Alfalfa under these conditions lost 6 per cent of its weight in the first 30 minutes, 14 per cent in 1 hour, and 32 per cent in 4 hours after cutting. On a bright day and with the same temperature as that prevailing on June 3 it is probable that the loss of moisture would have exceeded that of the mixture of tall oat-grass and orchard grass.

Determinations of the rate of moisture loss in alfalfa at Chico, Cal., have been made during several years, and these results are given in Table XI. These data appeared in slightly different form in an earlier

publication by McKee,¹ who called attention at that time to the fact that because some varieties of alfalfa after cutting lose moisture more rapidly than others the field weights will be incomparable unless sufficient time has elapsed to insure a uniform moisture content.

TABLE XI.—Rate of loss of moisture in alfalfa varieties during the early stages of curing, at Chico, Cal., in 1910, 1911, and 1912.

Time of weighing.	Time elapsed.			Arabian.			Peruvian.			Ordinary.	
	Days.	Hours.	Minutes.	Weight.		Loss in weight.	Weight.		Loss in weight.	Weight.	Loss in weight.
				Grams.	Pounds.		Grams.	Pounds.			
Test A:						<i>Per ct.</i>			<i>Per ct.</i>	<i>Grams.</i>	<i>Per ct.</i>
June 22, 1910.....				254.0	.....	0	276.0	.....	0	240.0	0
June 23, 1910.....		24		98.8	.....	61.1	129.7	.....	53.0	107.5	55.2
June 25, 1910.....		72		76.7	.....	69.8	91.6	.....	66.8	83.3	65.3
Test B: ¹											
June 9, 1911 ² —											
10.22 a. m.....				400.0	.....	0	400.0	.....	0	400.0	0
11.52 a. m.....		1	30	243.8	.....	39.1	271.3	.....	32.2	269.3	32.7
1.22 p. m.....		3		174.3	.....	56.4	212.3	.....	46.9	205.8	48.6
4 p. m.....		5	38	145.1	.....	63.7	172.9	.....	56.8	175.9	56.0
Sept. 27, 1911.....	110			83.6	.....	79.1	83.3	.....	79.2	82.5	79.4
Test C:											
June 9, 1911—											
9.07 a. m.....				.....	100	0	.....	100	0	.....	.....
11 a. m.....		1	53	.....	73	27.0	.....	78	22.0	.....	.....
2 p. m.....		4	53	.....	41	59.0	.....	48	52.0	.....	.....
4 p. m.....		6	53	.....	36	64.0	.....	42	58.0	.....	.....
June 12, 1911.....	3			.....	24	76.0	.....	24	76.0	.....	.....
Aug. 8, 1911.....	60			.....	22	78.0	.....	22	78.0	.....	.....
Test D:											
June 4, 1912—											
10 a. m.....				.....	100	0	.....	100	0	.....	.....
11 a. m.....		1		.....	78.5	22.5	.....	83.5	16.5	.....	.....
12 a. m.....		2		.....	60.5	39.5	.....	65.5	34.5	.....	.....
2 p. m.....		4		.....	34.5	65.5	.....	31.5	68.5	.....	.....
4 p. m.....		6		.....	26	74.0	.....	24.5	75.5	.....	.....

¹ The weights of test B are an average of two samples in each case. The leaves constituted 56.4 percent of the weight in the Arabian variety, 52.5 per cent in the Peruvian, and 49.8 per cent in the ordinary.

² First weight was taken about five minutes after cutting.

These data indicate very clearly that the rate of loss during the first four or five hours at Chico, Cal., greatly exceeds the loss during a like period at Arlington Farm, Va. This is doubtless due to both the higher temperature and the lower humidity of the atmosphere at Chico, the loss during the first 1½ hours at Chico being nearly equal to that during the first 3 hours at Arlington Farm.

In connection with these results it is well to note that the weighings of alfalfa at Chico were made in the month of June, while those at Arlington Farm were made in October.

It is also interesting to note that in tests B and C the Arabian variety lost moisture faster for the first few hours after cutting than the Peruvian or the ordinary alfalfa, but that in the end it had practically the same percentage of dry matter. A high percentage of leaves is usually thought to indicate a high moisture content, but the Arabian has 6.6 per cent more leaves than the ordinary, and yet the total moisture content is about the same for the two varieties.

¹ McKee, Roland. Arabian alfalfa. In U. S. Dept. Agr., Bur. Plant Indus. Cir. 119, p. 25-30, 1913.

VARIATION IN THE MOISTURE CONTENT OF GROWING ALFALFA DURING A SINGLE DAY.

In order to determine whether a different percentage of moisture is to be expected in forage plants cut at different times of the day, five samples of alfalfa were cut at 8 o'clock in the forenoon and six samples at 3 o'clock in the afternoon. The alfalfa was in a fairly vigorous condition and about one-tenth in bloom. The day was warm and sunny. A detailed statement of the results with each sample is given in Table XII.

TABLE XII.—*Moisture content of growing alfalfa at 8 a. m. and at 3 p. m., at Chico, Cal., in 1914.*

Sample.	Weight.				Moisture.		
	Green, June 13.	June 30.	Air dry, July 27.	Oven dry.	Original material.	Air-dry material.	Lost in air drying.
Cut at 8 a. m.:	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 549.....	123.2	33.70	31.95	28.5	76.9	10.7	74.1
No. 550.....	123.2	35.95	33.70	29.0	76.5	13.8	72.7
No. 551.....	123.2	35.70	32.45	29.5	76.1	9.1	73.7
No. 552.....	123.2	34.95	35.20	31.5	74.5	10.5	71.4
No. 553.....	123.2	34.95	34.95	31.5	74.5	9.7	71.6
Mean.....					75.7±0.216	10.8±0.346	72.7±0.231
Cut at 3 p. m.:							
No. 554.....	91.2	26.95	26.95	24.0	73.6	10.8	70.4
No. 555.....	91.2	26.45	25.70	22.5	75.3	12.2	71.8
No. 556.....	91.2	24.70	23.95	21.0	77.0	12.2	73.7
No. 557.....	91.2	26.20	25.70	22.5	75.3	12.3	71.8
No. 559.....	91.2	27.45	27.70	24.5	73.1	11.5	69.6
No. 560.....	91.2	26.70	26.95	24.0	73.6	10.8	70.4
Mean.....					74.7±.263	11.6±.127	71.3±.261

The mean for the two methods of treatment shows 1 per cent more moisture in the alfalfa at 8 a. m. than at 3 p. m. While this difference is not large, there is a sufficient number of samples so that the results are dependable. In actual practice this result has little significance, but it is of interest to find that in the open field under favorable moisture conditions transpiration may exceed the absorption of water by the roots sufficiently so that the moisture equilibrium in the plant tissues is not maintained.

MOISTURE CONTENT OF BALED HAY.

In order to give some idea of the amount of moisture in ordinary baled hay, samples were taken from oat hay in the bale at Chico, Cal., at two dates, the first about one month and the second about two months after the hay was baled. Ordinary commercial hay was used in this experiment, so the moisture percentage may be considered as fairly representative of that in the grain hays on the market in California. The moisture content, as determined by two sets of samples, is given in Table XIII.

TABLE XIII.—*Moisture content of baled oat hay and moisture lost in air drying at Chico, Cal., in 1914.*

Sample.	Weight.								Moisture.	
	July 1.	July 10.	July 20.	July 27.	Aug. 4.	Aug. 19.	Aug. 24.	Oven dry.	Original sample.	Lost in air drying.
	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Per ct.</i>	<i>Per ct.</i>
No. 561.....	44.5	43.00	43.25	42.75	.....	.....	.....	39.0	12.4	4.0
No. 562.....	44.5	43.00	43.25	42.50	.....	.....	.....	39.0	12.4	4.5
No. 563.....	44.5	42.75	43.00	42.50	.....	.....	.....	39.0	12.4	4.5
No. 564.....	44.5	43.25	43.50	43.00	.....	.....	.....	39.5	11.3	3.2
No. 565.....	44.5	42.50	42.75	42.25	.....	.....	.....	39.0	12.4	5.1
Average.....	44.5	42.90	43.15	42.60	.....	.....	.....	39.1	12.2	4.3
No. 591.....	.....	.....	.....	.....	44.5	43.25	43.00	39.5	11.3	3.2
No. 592.....	.....	.....	.....	.....	44.5	43.00	43.00	39.5	11.3	3.2
No. 593.....	.....	.....	.....	.....	44.5	43.25	43.25	40.0	10.0	4.0
No. 594.....	.....	.....	.....	.....	44.5	43.00	43.00	39.5	11.3	3.2
No. 595.....	.....	.....	.....	.....	44.5	43.25	43.25	39.5	11.3	4.0
Average.....	.....	.....	.....	.....	44.5	43.15	43.10	39.6	11.0	3.5

Thesamples described in Table XIII were taken from bales 566 to 570, used for the investigations recorded in Table XIV. This hay was baled on June 1, and the samples taken one month later had 12.2 per cent of moisture, while the five samples taken two months after baling averaged only 11 per cent of moisture. The weather during July and August was unusually dry and hot, so that the loss of 1.2 per cent of moisture from July 1 to August 4 is not excessive, even for baled hay. The 44.5-ounce samples which were inclosed in cotton bags and suspended under a shelter where the air could circulate freely about them lost in the same period an average of 4.3 per cent of moisture. This loss probably left the samples practically air dry, since the samples taken from the bales August 4 lost only 3.5 per cent during the period from August 4 to August 24.

SHRINKAGE OF HAY AFTER STORING AND VARIATION IN WEIGHT DUE TO CHANGES IN ATMOSPHERIC HUMIDITY.

In order to determine just what shrinkage in weight might be expected in baled hay and also the effect which radical changes in atmospheric humidity might have on this weight, four bales of oat hay were weighed at intervals during the season from June 1 to December 1, 1913, and five bales during the season from June 1, 1914, to February 25, 1915, at Chico, Cal. The record of these weights is given in Table XIV.

TABLE XIV.—*Shrinkage of oat hay after baling and variation in weight, due to changes in atmospheric humidity, at Chico, Cal., in 1913 and 1914-15.*

Bale.	Weight.								
	When baled, June 1.	July 7.	Aug. 1.	Sept. 25.	Nov. 4.	Dec. 1.	Loss, ¹ June 1 to—		Gain, ¹ Sept. 25 to Dec. 1.
							Sept. 25.	Dec. 1.	
Tests in 1913:	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 1.....	225.0	221.0	217.5	213.0	215.0	216.5	5.3	3.8	1.5
No. 2.....	240.0	231.5	230.0	227.0	230.0	231.0	5.4	3.8	1.6
No. 3.....	245.0	237.0	234.0	230.5	233.0	235.0	5.9	4.1	1.8
No. 4.....	265.0	256.0	254.5	252.0	253.0	254.0	4.9	4.2	.7
Average.....	243.8	236.4	234.0	230.6	232.8	234.1	5.4	4.0	1.4
	When baled, June 1.	July 1.	Aug. 31.	Oct. 16.	Dec. 17.	Feb. 2, 1915.	Loss, ¹ June 1 to—		Gain ¹ Aug. 31 to Feb. 25.
							Aug. 31.	Feb. 25, 1915.	
Tests in 1914-15:	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
No. 566.....	160	150.25	147.75	147.75	152.00	153.5	7.7	0.9	6.8
No. 567.....	190	176.50	172.50	172.50	175.25	182.5	9.2	3.9	5.3
No. 568.....	165	154.00	151.75	152.25	155.50	162.0	8.0	1.8	6.2
No. 569.....	200	189.00	184.50	184.50	187.75	194.0	7.8	3.0	4.8
No. 570.....	175	163.00	161.00	161.50	164.25	172.5	8.0	1.4	6.6
Average.....	178	166.55	163.50	163.70	166.95	173.9	8.1	2.2	5.9

¹ In figuring all the percentages, the original weight of the bale was taken as the base.

It is unfortunate that no determination of the moisture percentage was made for the hay used in 1913 and also that the weights were not continued through the winter, so that the gain due to increase of atmospheric humidity could have been more fully recorded. A comparison of the results in 1913 with those in 1914 indicates that the hay used in 1913 was somewhat drier than that used in 1914, since the total shrinkage was less; however, this may have been due, to some extent at least, to the character of the season. July and August in 1914 were unusually dry, while the months of December, January, and February, following, were extremely wet. The month of November, 1913, was also quite wet, having a precipitation of 8.5 inches and 21 cloudy or partly cloudy days. Under the extreme conditions in 1914, the variation in moisture content of the oat hay was quite large. The shrinkage in weight from the time of baling, June 1, to August 31, when the weight was least, amounted to 8.1 per cent of the original weight. Such a loss in weight would require the producer to advance the price of his hay considerably after holding it in storage several months, in order to protect himself against loss. The Ohio Agricultural Experiment Station¹ found a shrinkage of 5.7 per cent in baled oat straw when stored on a barn floor from September until

¹ Hickman, J. F. Experiments with oats. Ohio Agr. Exp. Sta. Bul. 57, p. 111, 9 tab., 1894.

March of the following year. Jordan¹ in his work at the Pennsylvania State College, 1882, found the loss of weight on hay stored in a barn to average 24 per cent. On this basis he figured that hay sold for \$10 per ton when taken from the field should bear a price of nearly \$12.50 per ton at the beginning of winter, provided no conditions affecting the price had changed other than loss in weight. Calculation indicates the exact price warranted by such a change in weight to be about \$13.15 rather than \$12.50 per ton. A loss of 8 per cent in weight when the price of hay was about \$10 per ton at baling time would require an advance of 85 cents to \$1 per ton, in order to insure the owner against loss.

Table XIV also shows that at Chico, Cal., baled hay following its loss of weight during the dry summer months takes up moisture during the wet winter months and gains back nearly all the weight lost, so that there is only a slight difference in weight between the time of baling and the weight at the end of the following February. The difference in this case was only 2.2 per cent, the hay having taken up 5.9 per cent of moisture between August 31 and February 25. This gain did not really begin, however, until after the October 16 weighing.

An almost equivalent gain was found in 1913, where the baled hay showed a gain in weight between September 25 and December 1 equal to 1.4 per cent of the original weight of the bale. At Chico, Cal., holding the hay until late winter would, it seems, overcome to a great extent any decrease in weight caused by loss of moisture during the summer months. This gain, however, takes place slowly. It appears from a consideration of the results obtained in both years that baled hay in a humid atmosphere will take up about 1.5 per cent of moisture the first month and in four months increase in weight approximately 6 per cent.

The shrinkage in loose timothy hay and the variation in its weight because of changes in atmospheric humidity are shown in Table XV.

The hay used in both lots 1 and 2 was practically pure timothy which was cut July 10. The hay in lot 1 was allowed to cure in the field and the 108.5 pounds were taken from the windrow July 11, when it appeared to be in about the right condition for placing in the mow. The hay in lot 2 was taken immediately after cutting and weighed, while green, 512 pounds. After weighing, it was spread out on a canvas and allowed to cure until the following day, being turned or stirred several times to hasten the drying process. On July 11 it was placed in burlap sacks and removed to a barn, where it was kept under the same conditions as lot 1. The first weighing of lot 2 was made on July 17, and even at this date it was evidently not so dry as lot 1 had been on July 11, although both lots appeared

¹ Jordan, W. H. Experiments and investigations conducted at the Pennsylvania State College, 1881-2, p. 7-14. Harrisburg, Pa.

dry enough on that date to place in a mow. The weight of the hay at this stage, when it was supposedly ready to be placed in a barn, is used as the base for figuring all percentages.

TABLE XV.—*Shrinkage of timothy hay after storing and variation in weight due to changes in atmospheric humidity, New London, Ohio, 1914.*

Date of weighing.	Lot 1.			Lot 2.			Weather conditions.
	Weight.	Percentage of original weight.	Loss in weight.	Weight.	Percentage of original weight.	Loss in weight.	
	Pounds.		Per cent.	Pounds.		Per cent.	
July 10.....							Clear.
July 11.....	108.5	100.0	0				Do.
July 17.....	103.5	95.4	4.6	295.25	100.0	0	Do.
Aug. 27.....	97.5	89.9	10.1	246.00	83.4	16.6	Rain, Aug. 6.
Sept. 2.....	101.0	93.1	6.9	250.00	84.7	15.3	Rain.
Sept. 11.....	99.5	91.7	8.3	250.75	85.0	15.0	
Sept. 21.....	97.5	89.9	10.1	242.25	82.1	17.9	Very dry.
Sept. 28.....	97.5	89.9	10.1	244.75	83.0	17.0	Clear.
Oct. 5.....	96.5	88.9	11.1	243.75	82.6	17.4	Cloudy.
Oct. 13.....	99.0	91.2	8.8	251.75	85.3	14.7	Rain on several preceding days.
Oct. 19.....	100.5	92.6	7.4	255.50	86.6	13.4	Cloudy and some rain on every day since Oct. 13.
Oct. 26.....				253.00	85.8	14.2	Clear from Oct. 20 to 23; Oct. 24, rain; Oct. 25, clear; Oct. 26, rain.
Nov. 2.....				250.75	85.0	15.0	Weather clear nearly all the time since Oct. 26.
Nov. 11.....				247.75	84.0	16.0	Weather clear since Nov. 2.
Dec. 2.....				252.00	85.4	14.6	Cloudy for four or five days preceding Dec. 2. Rain on two days.

The seasonal effect is not so marked in this instance as it was in the alfalfa at Chico, Cal., but the more frequent weighings provide an opportunity to observe the almost immediate response of loose hay to changes in atmospheric humidity. This point is illustrated best by the increase in weight during the period from October 13 to October 26, a maximum increase of 4 per cent over the weight registered on October 5 being noted on October 19. This decided increase in weight is accounted for by a period of almost continuous rain between these dates. Clear, sunny weather after October 26 caused sufficient loss of moisture to reduce the weight 2.6 per cent by November 11, showing that even as late as this in the season dry, sunny weather would affect the moisture content noticeably.

The average amount of shrinkage from a field-cured condition in lot 1 was 8.6 per cent, while in lot 2 the shrinkage was 15.6 per cent. A compilation¹ of the results obtained at several experiment stations showed an average shrinkage of 17.9 per cent in timothy when it was stored in a barn from 5 to 10 months. These figures represent fairly well the shrinkage that is to be expected in timothy hay which has been stored in a haymow, but more data on this point are needed.

¹ Vinall, H. N., and McKee, Roland. A digest of literature relating to the moisture content and shrinkage of forage. *In Jour. Amer. Soc. Agron.*, v. 8, no. 2, 1916.

SUMMARY.

The variation in moisture content in field-cured forage often gives rise to errors greater in amount than the differences in yield between improved varieties or different methods of culture.

A study of the use of samples in correcting forage yields indicates the following results:

(1) Air-dried samples are a little less accurate than oven-dried samples, but the difference is so small that the air drying of samples can be relied upon for all practical purposes in correcting forage yields.

(2) Much greater extremes are found in the samples of field-cured material than in the samples of green material, indicating that replication of samples is more important in the former than in the latter.

(3) Corrections by means of samples can be accurately made from either green or field-cured material, provided care is used in sampling.

(4) Considering accuracy of results, facility of handling, and ease in figuring percentages, 5-pound samples of field-cured material and 10-pound samples of green material are recommended as the most desirable sizes for practical use.

(5) Samples need not be replicated more than three times.

(6) The percentage of moisture in the different crops at that period of growth when they are ordinarily harvested for forage was as follows: Alfalfa at Chico, Cal., 75 to 78 per cent; average, 76.9 per cent. Alfalfa at Arlington Farm, Va., 74 to 76.5 per cent; average, 75.2 per cent. Tall oat-grass and orchard-grass mixture at Arlington Farm, Va., 71 to 73 per cent; average, 72 per cent. Timothy at New London, Ohio, when in full bloom, average, 67.2 per cent. Sorghum at Amarillo, Tex., 70 to 73 per cent; average, 71.2 per cent. These percentages are probably near the average for each crop, but the fact that McKee found 85.8 per cent and Farrell an estimated 79.5 per cent of moisture in alfalfa indicates that it will be impossible to establish any arbitrary percentage of moisture in the green plant as a basis for correcting forage yields.

(7) The average amount of moisture in field-cured material was as follows: Alfalfa, 22.3 per cent; timothy, 20.3 per cent; tall oat-grass and orchard-grass mixture, 29 per cent; sorghum, 43.2 per cent. The moisture content of field-cured material varies so widely that it can not be foretold with accuracy.

The use of the sample method in correcting forage yields would greatly assist in standardizing agronomic data and do much to promote greater accuracy in field tests.

The system of correcting yield data by the use of air-dried samples is of most value in succulent crops like sorghum and Sudan grass and is of least value in fine-stemmed plants like millet, which cure quickly and rather completely.

The relation of the moisture content to the stage of development in the plants was studied in alfalfa, timothy, and sorghum. The results were as follows:

(1) Alfalfa at Chico, Cal.: Very young (12 inches high), 78.9 per cent; one-tenth in bloom, 77.1 per cent; full bloom, 74.6 per cent; past full bloom, 73.4 per cent.

(2) Sorghum at Amarillo, Tex.: Very young, 90.6 per cent; shooting for heads, 87.1 per cent; beginning to head, 84.8 per cent; full bloom, 80.4 per cent; seed ripe, 75.3 per cent.

(3) Sorghum at Hays, Kans., varied from 89.2 per cent when very young to 73.2 per cent when seed was ripe, showing practically the same gradations as at Amarillo, Tex.

(4) Timothy at New London, Ohio: Very young (10 to 12 inches high), 77.5 per cent; just heading, 76.6 per cent; early bloom, 71.4 per cent; full bloom, 67.2 per cent; leaves drying, 58.6 per cent; seed mature, 51.2 per cent.

(5) The excessive percentage of moisture in young sorghum explains the very chaffy character of sorghum hay when the crop is cut too soon, and the 90 per cent loss in weight is an additional reason why sorghum should be fairly mature before it is harvested.

(6) The moisture content of any crop at a given stage of maturity is not constant, but may vary with the conditions under which the crop is grown.

A study of the rate of loss of moisture in forage during the early stages of curing shows the following results:

(1) The approximate losses in the different crops were—

Crop and location.	Moisture loss.				
	½ hour.	1 hour.	2 hours.	3 hours.	4 hours.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Alfalfa at Chico.....		17	35		69
Alfalfa at Arlington Farm.....		14	23	28	32
Tall oat-grass and orchard grass at Arlington Farm.....	5	12	24	30	34
Timothy at New London.....	6	10	18	25	30
Sorghum at Hays.....	2	5	9	12	13

(2) The rate of loss of moisture after cutting differs in different varieties of the same crop, as well as in different crops.

(3) Although the Arabian alfalfa loses moisture faster than the Peruvian or ordinary alfalfa in the first one or two hours after cutting, still the total percentage of moisture is about the same for the three varieties.

(4) A high percentage of leaf surface in alfalfa varieties is correlated with a rapid loss of moisture immediately after cutting, but it does not indicate a high moisture content.

Studies of the variation in the moisture content of growing alfalfa during a single day at Chico, Cal., show an average of 1 per cent more moisture in the alfalfa at 8 o'clock a. m. than at 3 o'clock p. m.

Studies of the shrinkage in hay after storing and variation in moisture content due to changes in atmospheric humidity made with baled oat hay at Chico, Cal., and loose timothy hay at New London, Ohio, indicate results as follows:

(1) At Chico, Cal., where the atmospheric humidity changes radically from the dry summers to the wet winters, baled oat hay showed a shrinkage in 1914 of 8.1 per cent between June 1 and August 31, and a gain in weight from August 31, 1914, to February 25, 1915, of 5.9 per cent of the original weight.

(2) The results at Chico, Cal., indicate that even baled hay responds noticeably to changes in atmospheric humidity, and that hay dealers are justified in taking into account the shrinkage of their hay when fixing prices.

(3) The results secured at New London, Ohio, with loose timothy indicate a shrinkage of 8.6 per cent in one lot and 15.6 per cent in another lot when the hay was stored in a barn for about three months. The effect of a week of rainy weather was indicated by an increase of weight in the loose hay.

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BULLETIN No. 354

Contribution from the Forest Service,
HENRY S. GRAVES, Forester



Washington, D. C.



October 20, 1916

FORESTS OF PORTO RICO; PAST, PRESENT, AND FUTURE, AND THEIR PHYSICAL AND ECONOMIC ENVIRONMENT.

By LOUIS S. MURPHY, *Forest Examiner.*

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INTRODUCTION.

Every year the people of Porto Rico consume over three times as much wood as the forests of the island produce. Great quantities of timber have been cut or burned by the "conuco" to make a clearing, which is abandoned after a few years and becomes a mere waste. The charcoal burner is still at work destroying the young growth needed to keep up the forest. Failure to put an end to the destructive practices that are rapidly reducing the forests or to provide the means of developing and fully utilizing them in a scientific manner has already brought about a shortage in the domestic supply of wood and consequent hardship to the people. It is the object of this bulletin¹ to give a complete account of the trees and the forests of Porto

¹ Under an informal cooperative arrangement between the Secretary of the U. S. Department of Agriculture and the Governor and Board of Commissioners of Agriculture of Porto Rico the author spent six months, from November, 1911, to May, 1912, on the island, making a first-hand study of its forest problems. A preliminary report of his findings and recommendations regarding these problems was published in the "First Report of the Board of Commissioners of Agriculture of Porto Rico," San Juan, Jan. 1, 1912, pp. 48-60. In this report it was recommended that the authority of the board be extended to cover the management of the forests; and that an insular forest service, with a qualified and experienced forester in charge, be established to carry on the work. This service could be established at a maximum cost of \$20,000 and maintained for \$8,000 or less a year, and would effect an annual gain to the island through the scientific management of its forests amounting to over \$350,000.

Rico, to show their value to the people of the island, and to suggest the means of improving them and making them permanent.¹

PHYSICAL AND ECONOMIC FEATURES.

Porto Rico is very sparsely wooded. The impenetrable forest jungles, commonly associated with the West Indies, are so scarce that one may cross and recross the island without seeing them, for, with the exception of those in the Sierra de Luquillo, they are tucked away in the more inaccessible places into which few except the "jibaro" ever penetrate. The island is, however, by no means devoid of wood growth. Around almost every habitation there are groups of trees, such as the bread fruit and mango; and numerous scattered single trees, mostly palms, dot the open landscape. The protective cover of shade trees of the coffee plantations gives a decidedly forested appearance to many localities.

Porto Rico presents an unusual combination of physical and economic conditions. The insular and geographic position of the country, its diminutive size, its restricted area of level lands, and its density of population, to mention but a few of many influences, have occasioned unusual demands on the forests. The same cycle of change is found here as is recorded by civilization everywhere—a profligate waste and despoliation of the bounties of nature, followed by an acute need for what has been destroyed.

GEOGRAPHIC SITUATION.

Porto Rico is the easternmost and smallest of the Greater Antilles and is well within the Tropics. It is situated between latitudes 17° 54' and 18° 30' north and longitude 65° 35' and 67° 15' west, occupying a position about midway in the chain of islands connecting Florida and Venezuela and separating the Carribean Sea from the Atlantic Ocean. It is about 450 miles east and slightly south of the nearest point of Cuba; about 500 miles north of the nearest point of Venezuela; about 1,000 miles from Colon (Panama); about 1,500 miles from New York and New Orleans, and a little more than twice that distance from Gibraltar.

¹ In addition to new material the present bulletin revises and brings up to date two previous bulletins of the Forest Service: "Notes on the Forest Conditions of Porto Rico," by Robert T. Hill, Bulletin 25, Division of Forestry, Department of Agriculture, 1899, and "The Luquillo Forest Reserve, Porto Rico," by John C. Gifford, Bulletin 54, Bureau of Forestry, U. S. Dept. of Agriculture, 1905.

It is appropriate to acknowledge in this place the author's indebtedness to the works enumerated above and in the bibliography. Special acknowledgment is due to the officers and employees of the Insular Government and of the Porto Rico Agricultural Experiment Station (U. S. Dept. of Agriculture) for giving the author access to official unpublished data and personal assistance in locating and getting to the various places visited; to Mr. Paul Buffault, Conservateur, Administration des Eaux et Forêts, France, and Mr. Thomas R. Wallace, American consul at Fort de France, for valuable information concerning forest conditions and legislation in Martinique (French West Indies); also to the Office of Acclimatization and Adaption of Crop Plants of the Bureau of Plant Industry, Department of Agriculture, for the use of photographs comprising Plates I, IV, and VI, fig. 1.

Porto Rico has a total area of 3,435 square miles (2,198,400 acres).¹ The main island is 3,349 square miles in extent, and the islands of Vieques, Mona, Culebra, and other adjacent smaller islands within its governmental jurisdiction are 51.5, 19.5, 11, and 4 square miles, respectively. The territory as a whole is thus about five-sixths the size of Jamaica or the island of Hawaii, seven-tenths the size of Connecticut, and four times as large as Long Island.

In general outline it is almost a geometrically regular parallelogram, approximately 100 miles long and 35 miles wide. Its longest dimension lies east and west. The sea line is nearly straight and the coast is usually low, especially on the southern side, although there are a few headlands. The only protected harbors are San Juan on the north coast, Guanica and Jobos on the south, and Ensenada Honda on the southeast. The remaining ports, such as Arecibo, Mayaguez, and Ponce, are scarcely more than open roadsteads.

PHYSIOGRAPHY AND SOILS.

Porto Rico and the other islands of the Antilles and Central America and northern South America were formerly, according to geologists, a united and distinct continental

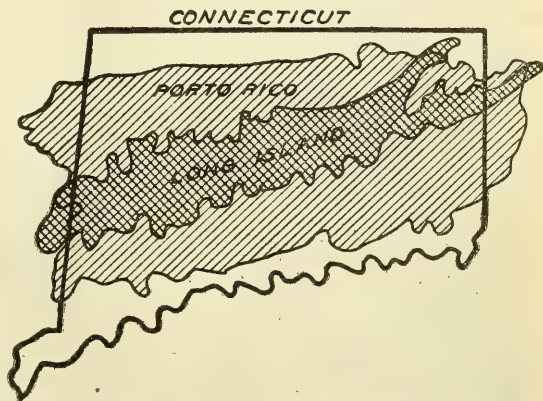


Fig. 1.—Porto Rico compared in size with Connecticut and Long Island, New York.

land mass—the Antillean continent. Then came a great subsidence, which left only the tops of the mountains above water. After a while the ocean floor was again thrust up, the old continent reappearing. The sediment of which it was composed, covered in the meantime by deep-sea muds and chinks, was then folded into huge mountain systems, individual peaks reaching as high as 20,000 feet above sea level. Another but lesser subsidence of the Antillean continent accomplished its breaking up into the present island groups, Jamaica being the first to be isolated, then Cuba, and finally Porto Rico and Haiti.

There are at the present time three main physiographic regions of the island of Porto Rico—a central mountainous core of volcanic

¹ "Areas of the United States, the States and Territories," Bulletin 302, U. S. Geological Survey. This area is the one officially determined upon by the U. S. Geological Survey, the General Land Office, and the Bureau of the Census, and is based on computation from the U. S. Coast Survey map. The detailed figures concerning the areas of the smaller islands were obtained directly from the Office of the U. S. Coast and Geodetic Survey.

origin, an elevated area of coral limestone (former marginal marine deposits) surrounding the mountainous portion, and the coastal plain.

CENTRAL MOUNTAIN AREA.

The central mountain area occupies by far the largest portion of the island. Viewed from the sea it presents a rugged and serrated aspect; numerous peaks and summits, with no definite crest line, rise from a general mass, which has been cut by erosion into lateral ridges, separated by deep, steep-sided gorges. The drainage divide is approximately parallel to the southern coast and about 10 or 15 miles distant from it. The region thus has a long and relatively gentle inclination toward the north coast, but falls off rather abruptly toward the south.

The Sierra de Luquillo,¹ the most easterly of the three ranges making up the central mountain mass, is surrounded by low coastal plains, and is completely isolated, except for a low water-divide which crosses near Las Piedras to the Sierra de Cayey. By thus completely dominating the landscape it gains the appearance of being very high; and one of its peaks, El Yunque (the anvil), has been credited with being the highest eminence on the island. According to the most recent determinations² this peak reaches an altitude of 1,062 meters (3,483 feet). The east peak has an elevation of 1,054 meters (3,457 feet) and the west peak 1,020 meters (3,346 feet).³ These higher peaks are flanked by numerous lateral ridges which extend in every direction. The valleys, known as "quebrados," are deep and gorgelike and are separated one from another by very narrow, almost knife-edged ridges, "cuchillas." Falls, cascades, and rapids are conspicuous features of the drainage system here. This range supports the only large tract of virgin forest growth on the island.

The remaining mountain mass forms an uninterrupted expanse of broken uplands. The main crest line extends from Humacao on the east through Aibonito and Adjuntas to within a short distance of Mayaguez on the west coast. The portion east of Aibonito is known as the "Sierra de Cayey;" that to the west, the "Cordillera Central." This region has an average elevation of about 2,500 feet, above which the higher peaks project irregularly, a few to an elevation of more than 3,500 feet. The thirteen highest peaks on the island are in the "Cordillera Central." The highest of these (not named on the Coast and Geodetic Survey chart) situated about due south of Jayuya, has an

¹ Herrera (see Bibliography) describes the Luquillo as follows: "Ten leagues East-South-East from the City of Puerto Rico is a very high and great Mountain, with three Breaks on it, call'd del Luquillo, or of the little Madman, on Account of a revolted Indian [that withdrew to it. The highest Point of it is call'd Furzidi, a Name given by the Blacks, signifying a place always clouded, and the third is call'd of the Holy Ghost."

² U. S. Coast and Geodetic Survey Chart 920, issued July, 1910.

³ These two together appear to be given the name "El Cacique" (The Indian Chief) by Gifford. He also names the round mountain to the west "El Toro" (The Bull), and the mountain next to it on the south "El Carnero" (The Sheep).



F-19769A

OPENING IN VIRGIN STAND OF MIXED TROPICAL HARDWOODS. RAIN-Forest FORMATION
NEAR LA ISOLINA (ARECIBO).

elevation of 1,341 meters (4,398 feet), while "Mt. Guilarte," commonly considered second to El Yunque, is 1,204 meters (3,950 feet).

The many lateral ridges which diverge from the central mountains, mostly from the north side, are commonly very steep-sided and narrow-crested, and the valleys are deep, V-shaped, and almost devoid of level bottom land. Rock outcrop is generally infrequent, except toward the outer portion, where the ridges are often capped with hard limestone.

The central mountains are composed largely of black or other dark-colored igneous rocks, which occur in the form of tuffs, conglomerates, silts, and an occasional dike of diorite. Their volcanic forms have been destroyed by erosion. The material thus worked over into sediment in prehistoric ages now occurs in well-defined strata. Two relatively inconspicuous limestone formations also occur, one black, bituminous, and shaly, and the other light gray and crystalline.

As a result of the almost uninterrupted action of an abundant precipitation, a high relative humidity, and a warm temperature, rock weathering at the higher elevations is more rapid than erosion, as shown by a soil mantle of unusual depth and almost no bare indurated rock here. The characteristic soils are deep, reddish clay loams and tenacious red clays. So cohesive, unctuous, and compact are these soils that they are able to maintain themselves in an almost vertical position. Cultivation, in consequence, is in many places carried on to the very tops of the ridges and on the steepest slopes, yet evidence of excessive erosion and landslides is surprisingly inconspicuous. At the lower elevations the sandy character of the soil and the more common occurrence of outcrop show that the rate of rock erosion has exceeded that of weathering.

THE CORAL LIMESTONE BELT.

The belt of coral limestone is several miles wide in places and on its interior border overlaps the igneous rocks. This area is of sedimentary origin. Where rock solution has been the most active agent of decay, it retains the general form of a table-land. Where erosion has been the most active only isolated conical hills remain. In certain parts of the island the limestone extends directly to the water's edge, where it terminates in steep scarps, often 100 feet or more in height, notably on the south coast west of Ponce and on the north coast west of Quebradillas. Elsewhere on the island the remnants of this formation stand as steep, sloping, solitary mounds or domes, which rise singly or in chains above the coastal plain.

Along the junction of the central mountains and the limestone belt is a distinct line of weakness marking the former shore line. Strong valley lines are developed there, separating the two physiographic regions. These "parting valleys" are especially well developed on the

south side of the island in the valley of the Guanajibos at Sabana Grande, and on the north side at the junction of the Don Alonso (or Limón) and Arecibo Rivers.

An uninterrupted block of limestone formation, known in places as the Pepino Hills,¹ occurs along the north side of the island from Ciales nearly to Aguadilla, and is some 6 to 10 miles wide from north to south. It offers a marked contrast to the low rounded limestone hills which flank it to the north, because of its greater elevation, rough, angular topography, pitlike valleys, bare rock outcrops of chalky whiteness, and subterranean drainage. Wherever the large rivers, such as the Rio Grande de Arecibo and the Manati, cross this area they have cut deep canyonlike valleys whose sheer cliffs of considerable height occasionally rise directly from the water's edge. Otherwise the area is strikingly devoid of surface drainage features. The hills are very closely packed together, their connecting ridges hardly more than rocky septums separating the disconnected pitlike valleys. The steep-sided depressions show, on a tremendous scale, to what an enormous extent rock solution takes place under tropical conditions.

The region, if viewed from above, would look like a honeycomb. Not infrequently the "sinks" are 100 feet and occasionally 200 feet or more deep. The larger pits sometimes contain an acre or more of bottom with a very fertile soil, commonly under cultivation to such crops as coffee, bananas, and ground provisions. The bottoms of others are occupied by bogs or small lakes. The crags and summits are almost invariably wooded. Caves, which mark the early stages of pit formation, are common.

Travel here is extremely difficult. Roads are out of the question and the trails are not numerous and are extremely rough. There is no alternative but to cross the pits in succession, descending to the bottom of one and then climbing to the rim of the next almost straight down and straight up again.

THE COASTAL PLAIN.

The sandy ridge fronting the coast forms a barrier between the sea and a narrow low-lying area scarcely above tidewater level, and partly marine and partly alluvial in origin. On the north side of the island there are many swamps and lagoons covered with a thick growth of mangrove bushes. The most typical are the Caño y Laguna de Tiburones between Arecibo and Barceloneta, Laguna del Tortuguero north and east of Manati, and the string of lagoons east of and connected with the harbor of San Juan. On the south side,

¹ The term "pepino" (cucumber) undoubtedly refers to the appearance of the elongated mammillary summits of the hills. An equally characteristic term, "cockpits," applied to a similar formation in Jamaica is descriptive of the valley bottoms.

the mangrove is only slightly developed, but there are in places extensive saline plains too low and wet for cultivation, where rank grasses, a few scattered acacias, or low, succulent, salty herbs constitute the only vegetation.

The coastal plain proper is elevated but a few feet above the sea, and has but a slight gradient toward the mountains. It terminates rather abruptly at the foothills, except in the valleys of the larger rivers. These plains are entirely sedimentary, having been laid down when the island stood at a somewhat lower level than now.

The coast-plain hills are isolated, low, and dome-shaped. Some have been nearly buried by the alluvial deposits of the rivers; others rise 100 feet or more above the level of the plain.

The soil, except on the hills, is largely a fine, rich alluvium, sandy in places, and is almost entirely under cultivation or in pasture.

DRAINAGE.

It would be difficult to find another country of its size so well watered as Porto Rico. Within the mountainous area are many swift-flowing streams which have cut for themselves deep, steep-sided valleys. In their upper courses they traverse steep, angular gorges, where numerous cascades and cataracts are to be found, particularly in the Sierra de Luquillo. The peculiarity of the drainage system where it passes from the central mountain into the limestone region has already been described. Within the coastal plain the valleys are broad, with considerable areas of bottom land through which the rivers pursue a meandering course. The streams flowing north from the main divide are much more numerous and longer than those from the south side, and they likewise carry a much greater and more constant volume of water. The island is reported to have upward of 1,300 named streams, of which the Rio de la Plata is considered the longest, about 45 miles. None of the rivers is navigable, except for small boats, and then chiefly in their tidal reaches. They, nevertheless, are of tremendous importance as a source of domestic water supply, and their power possibilities are also very considerable.

CLIMATE.

WINDS.

Though Porto Rico is well within the Tropics, it has an equable and comfortable climate, for the modifying influences of the ocean are accentuated by its position in the direct path of the North Atlantic trade winds. These counteract the enervating effect of the high temperature and humidity, the occasional periods of sultry and oppressive weather invariably occurring when they fail. They vary in direction from northeast to southeast, usually coming from east or east-southeast. Their average velocity from month to month is

remarkably constant, rarely varying more than a mile from the annual average of 11 miles per hour, excepting in July, when the velocity rises to 13 miles, and in October and November, when it falls to 8 or 9 miles.

Hurricanes whose centers pass over the island are rare; in the past 40 years there have been but three, the most recent as well as the most destructive being that of August 8, 1899. The recorded storms of this character for the entire West Indies average about one a year and occur chiefly during the months of August, September, and October.

TEMPERATURE.

The temperature throughout the year is uniform. The records of the United States Weather Bureau for a period of more than 10 years show a combined average annual temperature for over 40 stations in the island of 76° ; during the coolest months of winter the average is 73° and during the warmest months of summer 79° . The daily range is much more than the seasonal range; thus at San Juan the difference between the afternoon and early morning temperature is 10° or 11° and at an inland station may be as much as 20° or 25° . In the afternoon the temperatures along the coast rise to an average of 84° in the winter months and to 89° in the summer months and in the early morning fall to 66° and 73° . In the hills and mountains of the interior the average daily maximum is about 81° in winter and 87° in summer, while the corresponding minima are 61° and 68° , respectively.

The extremes of temperature recorded during the past 10 years do not differ greatly in different portions of the island. At the more elevated stations the maximum range is between 90° and 95° and along the coast and in the valleys 95° and 100° . The extreme maximum has reached 100° only three times during the 10 years, at one time reaching 103° . The minimum temperatures range between 50° and 55° except for stations on the immediate coast, where the temperature seldom goes below 60° . The lowest recorded temperature is 43° , and it is probable that on the highest elevations it goes somewhat lower. It is, however, extremely doubtful if it ever approaches very near to the frost line.

RAINFALL.

The average annual rainfall is much more variable than the temperature. The average for a 12-year period from 44 stations shows 77.30 inches; for the year 1901 it was 93.72, and for 1907 but 64.18. The geographic distribution of rainfall shows a still wider variation. The heaviest is recorded in the Sierra de Luquillo, which is exposed to the full sweep of the moisture-laden trade winds. The average annual rainfall here exceeds 135 inches, with a maximum

record in 1901 of 169 inches. There are two other well-defined areas where the average annual rainfall exceeds 100 inches, namely, the peaks about Adjuntas and the mountains surrounding Las Marias and Maricao, San Sebastian, and Lares, in the central and west-central portions, respectively, of the Cordillera Central. These centers of heavy precipitation are likewise centers of heavy forestation. Except for the Luquillos, the forests are artificial ones, being largely coffee plantations, yet their influence on climate is in all respects similar.

While abundant rain and the absence of protracted droughts characterize conditions on the north side of the island, the reverse obtains to the south, where several months may elapse with little or no rain. Here precipitation is not only scanty but unevenly distributed throughout the year. The average annual rainfall for the stations along and near the south coast is 45 inches. The minimum average annual rainfall of 37 inches is recorded at Guanica, while 21 inches in 1907 is the absolute recorded minimum of recent years.

The rainfall on the whole island increases from 11 inches in the winter months (February being the lightest) to 16 inches during the spring, 23 inches during the summer, and 26 inches during the fall. The maximum generally occurs in September on the east coast, in October along the south coast, and in November along the north coast. The rainfall is largely in the form of showers, which, although frequently very heavy, seldom last over 10 or 12 minutes. Rain for a day or more at a time is comparatively rare.

Rain falls practically every day in the year over some portion of the island, except possibly a few days in February. For the island as a whole the average number of days in a year with rain is 169, the minimum and maximum frequency are 28 at Guanica on the south coast in 1907 and 341 in the Sierra de Luquillo in 1900, respectively. The average humidity for the island is about 78 per cent, the minimum in the driest month, 75 per cent, and the maximum in the most humid, 81 per cent.

LAND DISTRIBUTION, UTILIZATION, AND TAXATION.

LAND DISTRIBUTION.

The land policy of Spain appears to have been conceived in a spirit of great liberality. It not only provided for the usual extensive grants to the grandee and to the soldier of fortune, but also offered encouragement to the bona fide settler of small means. The first law,¹ promulgated by Ferdinand V under date of June 18, 1513, a scant 20 years after the discovery of America, granted settlers free title to holdings of something in excess of 170 acres, upon compliance with

¹ "Law First" (See Recapitulation de Leyes de los Reinos de las Indias, Book 4th, Title 12th). Translation by Bureau of Insular Affairs, War Department.

certain requirements concerning residence and cultivation, resembling very strikingly our own national homestead act, passed 350 years later.

GOVERNMENT LANDS.

By 1830 the Government had disposed of approximately half of the island, and between that time and the Spanish-American War had given away about nine-tenths of the remainder. The rest of the Crown lands, which, by the Treaty of Paris, December 10, 1898, became the property of the United States, amount, as nearly as can be ascertained from the records,¹ to 147,971 acres, of which 7,400 acres are classified as swamp land. These lands, except a small amount reserved for Federal use, were ceded by act of Congress approved July 1, 1902, to the people of Porto Rico. Some 3,000 acres in addition have reverted to the local government in default of taxes. Thus the entire public domain, including Federal and insular lands, amounts to less than 151,000 acres.

By far the greater part of this land lies in the mountains. Except for a few of the more accessible tracts, comparatively little is known about its present condition, or even its location, since in only one or two instances has any survey or detailed examination been made. General information gathered in the vicinity of some of the larger tracts indicates that only a very small amount of this land supports a productive forest, except a tract in the Sierra de Luquillo. The greater part is at present an idle, unproductive, grass or brush covered waste. In some few instances it is so situated as to be suitable for coffee culture, but in the aggregate it is of slight agricultural value, though it has a large potential value as forest land.

PRIVATELY OWNED LANDS.

Figure 2² indicates for the years 1828, 1900, and 1912 the comparative areas of public lands and of private lands under cultivation to different crops, under pasture, and under forests.

In 1828, while slightly over half of the island was privately owned, scarcely more than 3 per cent was under cultivation. Agriculture was then carried on largely for the production of home staples. Thus plantains, Indian corn, and rice covered more than half, while the commercial agricultural staples of to-day, cane, coffee, and tobacco, together covered scarcely one-fourth of the whole cultivated area. Between 1828 and the end of the Spanish régime the area under cultivation had increased to about 13 per cent. Nearly half of this was in coffee, and somewhat more than one-fifth of the remainder in cane.

¹ See report of the Commissioner of the Interior for Porto Rico, 1909.

² Compiled from Flint's "Porto Rico," containing the official returns for 1828, from Knapp's "Agricultural Resources and Capabilities of Porto Rico," and the summary of tax assessment (corrected to Aug. 10, 1912) in Report of the Governor of Porto Rico, 1912.

During the same period the area of so-called pasture land had more than doubled, so that it exceeded in extent all the other land classes combined, and privately owned forests had increased slightly. Private ownership was thus almost doubled, having absorbed nearly 95 per cent of the total land area.

During the period of American occupation the cultivated area has nearly doubled, amounting in 1912 to 23.28 per cent.¹ Of this area cane covers a trifle more than two-fifths, coffee more than one-third, minor fruits about a fifth, and tobacco, coconuts, oranges, and pineapples, in the order named, the remainder. This agricultural expansion has been carried on about equally at the expense of "pasture" and "timber and brush" lands. On account, however, of the much greater area of pasture lands, these were relatively little affected in the aggregate, while the forest lands were reduced nearly two-fifths.

There is no information available showing the average-size holdings in the various classes of property or in what proportion the economically developed lands are held in conjunction with the waste and forested lands. The data upon which the diagrams (fig. 3) are based most nearly approach this information by showing for the assessment area analyzed the proportion of the total, "by number" and "by area" of the farms in certain acreage groups.

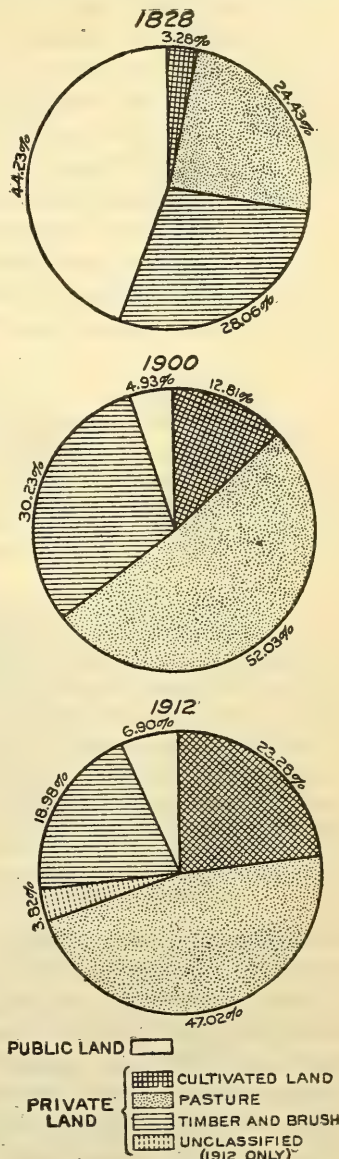


FIG. 2.—Land in Porto Rico. The changes from public to private ownership and the main uses to which it is put.

¹ This figure differs from the one (56 per cent) given in the Register of Porto Rico for 1910, which also varies from the so-called "improved area" (75.3 per cent) given by the Thirteenth Decennial Census (1910). Both of these percentages have included in them a considerable area of so-called "pasture" land. The grass land in the low country might be considered "improved," because it is used part of the time as pasture and is then plowed up and put into cane, but it is impossible to conceive of more than one-fourth to one-half of the total land classified as "pasture" as being thus alternately cropped and pastured. This would make the "improved" acreage aggregate 35 to 50 per cent of the total territorial domain. The remaining one-half to three-fourths of the land classed as "pasture" could more properly be classed as waste land or "ruinate," as is done in Jamaica and elsewhere, because it serves no productive economic use.

We find 91.34 per cent of all farms have an area less than 100 acres each, which would indicate a wide popular distribution of the land in small holdings. But the average area per farm in this group is only 21.4 acres; so that by far the greater number of individual holdings must be much less than 20 acres.¹ It is not surprising, therefore, that the remaining 8.66 per cent of the whole number of farms covers 55 per cent of the total farm area, or that these farms have an average of about 280 acres per farm.

With 93 per cent of the land in private ownership, the success of any reforestation work attempted by the Government will depend in a large measure upon the cooperation which can be secured from the private landowner. The conditions are the most unfavorable in the mountain region, where there is a considerable proportion of

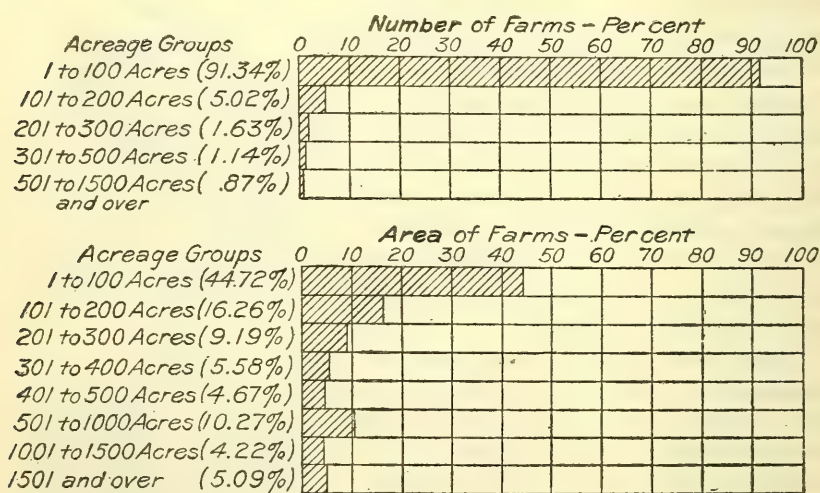


FIG. 3.—Distribution of land ownership in Porto Rico by acreage groups and number and area of farms.
From data compiled by bureau of property taxes, Government of Porto Rico.

small holdings, from which as a class very little cooperation can be expected. In addition to the small farms, there are a few coffee and tobacco plantations. Much of the land, however, is not even under small-farm cultivation. Vast stretches of it are nothing more than grass land, which is classed for assessment purposes as "pasture." In the coastal country the holdings are larger and offer better possibilities for cooperation. Many of the coast hills are already wooded, while others have been cleared for pasture. Here the need for forests on account of their protective influence on water and soil is not of importance, but the demand for wood is obviously urgent. Forests are needed in this particular section also as a refuge for birds, which are an important factor in controlling insect pests in the cane fields, besides being of esthetic value.

¹ According to the census of 1899, 51 per cent of all farms were less than 5 acres in extent, while the Thirteenth Decennial Census (1910) reports 72 per cent of all farms less than 19 acres in extent.

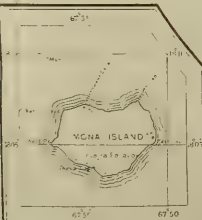
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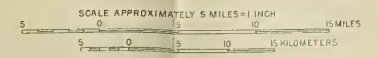


C A R I B B E A N S E A

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
HENRY S. GRAVES, FORESTER
PORTO RICO
AND CONTIGUOUS ISLANDS
UNDER ITS JURISDICTION

FROM DATA BY THE WAR DEPARTMENT
U.S. COAST AND GEODETIC SURVEY AND
DEPARTMENT OF THE INTERIOR
OF PORTO RICO

- LEGEND
- Insular Roads Completed
 - - - Insular Roads Projected
 - Trails
 - Telegraph Lines (Along Roads)
 - Canals (Irrigation or Drainage)
 - +1079 Location & Elevation of Peaks (by U.S.C.A.G.S.)



LAND UTILIZATION.

Porto Rico is essentially an agricultural country and will undoubtedly continue as such. Of its commercial staple crops—sugar, coffee, and tobacco—only the first two are important competitors of the forest from an acreage point of view, tobacco occupying less than 1 per cent of the insular area. Coffee cultivation is a most satisfactory form of agriculture for the steep mountain slopes where it is carried on and its replacement of the forest is usually justified, for it exerts many of the beneficial influences of the forest and few of the detrimental ones of the field crops. Sugar might be said to offer little economic competition with forests, because it usually occupies the more level and strictly agricultural soils.

Cattle raising was early taken up, and there was formerly a very considerable export trade in live stock, hides, and tallow. The total live stock now on the island amounts to not more than 350,000 to 400,000 head, and there is no export trade whatever. Cattle and horses make up nine-tenths of the stock (cattle alone three-fourths), the larger part of which is work stock. These are, to a considerable extent, used in the low country and are grazed in the pastures there. There seems, therefore, to be little economic justification for any longer retaining the bulk of the cleared uplands in pasture. Their partial or complete reforestation would add materially to the productive wealth of the island.

It is in the cultivation of native ground provisions—rice, yams, and the like—that agriculture comes into closest contact with the forest. From time immemorial, not only in Porto Rico but throughout the Tropics the world over, the same primitive agricultural practice has prevailed. Wherever it is in operation the “conuco,” or by whatever other name¹ the method is known, is essentially the same. Upon the area which it is desired to cultivate all the trees are felled and set on fire. Sometimes the larger ones are killed by girdling and allowed to remain standing. Clearing is most apt to occur during the dry season, when conditions are most suitable both for burning and for planting the new crop. Little or no care is taken to control the fire and it often burns over a far greater area than is wanted for cultivation. The beans, rice, or other ground provisions are planted immediately following the burning, the ashes having enriched and sweetened the soil. Little or no cultivation is given the crop, and cropping seldom continues for more than 3 years. Eventually, as the fertility of the soil decreases and grass, weeds, and other volunteer growth get the upper hand, the area is abandoned and a new clearing made.

¹ What is known as the “conuco” in Porto Rico and other of the Spanish West Indies is known in the Philippines as *caifin*, in India variously as *jhum*, *kumri*, and *khil*, in Burma as *juangya*, and in Ceylon as *chena* or *hena*. The same practice is also reported from the Sudan, Central America, and many other parts of the Tropics.

The best types of forest are invariably the ones first selected, because they give the richest ash and are less difficult to clear than areas of small, thorny growth. Thus for a meager crop of native provisions a valuable timber crop is destroyed, which it will require a generation and more to reproduce.

Where the amount of available land is scarce an area may be successively cut over several times at intervals, the parts cleared becoming naturally reforested again between cuttings. Where, however, climatic, particularly moisture, conditions are not favorable it may be difficult or impossible for the forest to reestablish itself in competition with a grass cover. In such cases the succeeding forests may grade from a dense thorny growth through chaparral and low brush, or a very fragmentary scattered tree growth, to open savanna and even desert. It is almost certain that the vast and almost totally unproductive area of so-called pasture land in the central mountain section is the direct result of this practice, which is even now being extensively carried on in all its primitiveness.

The total lack of property survey, lax title registration, and the free and unmolested operation of the prescriptive right have made it easy for this devastating practice to thrive. Legislation can and ought promptly to be undertaken to eliminate these contributory causes. But the government must go farther. There must be a serious educational campaign combining, unifying, and extending the work of the public-school system, the agricultural experiment station, and any other agencies working for rural betterment, until there can be instilled into the mind of the "conuco" farmer a proper regard for the fundamentals of economic agriculture, by which continuous cultivation under a suitable rotation of crops will be substituted for the present nomadic system. To give force and effect to that campaign the government must, of course, provide these people with the means of acquiring the land and other essentials to the practice of such improved agriculture.

TAXATION.

The same archaic provisions are in force in Porto Rico for the taxation of forest property as are to be found throughout the United States. The system of taxing the forest annually is unjust and discriminatory, encouraging forest destruction. In a country like Porto Rico, with practically no forest resources, it becomes prohibitory as well. Certainly few will elect to plant new forests or apply forestry to improve the productiveness of forests already there if by so doing they merely invite an increased assessment and taxes. The system, in fact, offers a distinct incentive to the owner to destroy what timber there is, so that there will remain but the bare land to tax.

Under these circumstances the law should make it possible for the forest to be classed as a crop. The growing of a forest is no less desirable to encourage than the growing of a crop of sugar cane, coffee, or tobacco; yet these latter are exempted entirely from taxation, while the forest is classed as an "immovable" and taxed annually at its full value. There is little wonder, under these circumstances, that no effort is made to practice forestry, which would inevitably increase the extent and value of the forest; or that the value of this class of property has decreased regularly from year to year, and for the fiscal year 1912-13 amounted, both timber and land together, to but 3.3 per cent of the total assessed value of all real property.

The law should at least provide that the land and timber be classified, assessed, and taxed independently of one another. The average forest crop requires several years, often decades, to mature. During this period it yields little or no revenue whatever. It is only fair to the producer of such a crop that his taxes be arranged to fall due in large part at the time when the crop matures and is sold. This may be accomplished in one of three ways. If the owner pays throughout the entire period a tax based on the full productive value of the bare land, then the timber should be exempted entirely. At most it should be taxed but once—on its sale value as it stands in the forest in the year that it is cut. The rate in this case should be the same as that applied to all other real and personal property for that particular year. A second method is to defer collecting any tax on the land until the timber is cut and then to take both the land and timber tax out of the sale value of the standing timber in that year. The rate in this case would, of course, have to be considerably higher than the general property tax rate and would properly be graduated according to the length of the period since the previous tax was paid. A combination of these two methods, modified according to circumstances, though less just to the landowner, would be at once an advance over the present plan and the most likely to be acceptable to the community. Thus an annual tax on the land would be levied either at the full general property rate on a nominal fixed value for the bare land or at half or other fractional part of the general property rate on the full productive value of the bare land. Then when the timber was cut, it, too, would be taxed, but at a rate correspondingly higher than the general property rate, say 10 per cent.

Porto Rico is fortunate in that it has no constitutional obstacles to remove before it can proceed to a change. Neither the organic act nor any of the subsequent acts of Congress puts any specific restrictions on taxation. It is only necessary, therefore, in order that this unjust discrimination against forests and forestry may be removed, to induce the legislative assembly to amend the present law.

A decidedly favorable feature of the present taxation system of the island is its centralized organization. The insular government assumes the responsibility for the assessment and collection of all taxes, general and municipal, thus reducing the chances of inequalities being introduced between urban and rural properties, and between similar classes of property in different municipalities. Until, however, there can be effected a complete cadastral survey of the island, making possible the enforcement of compulsory title registration and the assessment of land values based thereon, any system of taxation, no matter how adequate, must, as now, be a dead letter in its real property provisions; and the present practice of "distraining personal property for all taxes due and only proceeding on real property when no personal property exists" must continue.

POPULATION.

Porto Rico has had a steady increase in population since Columbus found 30,000 native Indians¹ on the island, except in the early years of settlement, when through conflict, disease, emigration, and slavery, the native population was rapidly reduced to a state approaching extinction. Although it was reported in 1543 that but 60 Indians remained on the island, it is probable that relatively pure Indian stock persisted in the mountainous sections up to comparatively recent times.² Here, too, the aboriginal type of feature is readily discernible to-day and the primitive method of "conuco" cultivation is most commonly encountered.

Because of extensive slave importations almost from the beginning of settlement and the correspondingly slow colonization up to the middle of the eighteenth century, as late as 1820 the negro population outnumbered the white by 5 to 4. At present, however, the white race dominates all others by more than 7 to 4. Except for Cuba, there is no other island in the West Indies where this condition is even closely approximated, all but two showing 10 per cent or less of white people. Porto Rico has also a smaller proportion of negro population than most of the southern seaboard States.

The density of population in Porto Rico is phenomenal, particularly as there is a great preponderance of rural inhabitants. It is exceeded in but few of the other West Indies, is 1 per cent more than in China, and slightly more than in Japan. Porto Rico, with 325.5 persons per square mile (79.9 per cent rural), ranks fourth among the political subdivisions of the American territory,³ after Rhode Island with 508, Massachusetts with 418.8, and New Jersey with 337.7. On the

¹ Fewkes, Jesse Walter, "The Aborigines of Porto Rico," 25th Annual Report, Bureau of Ethnology, 1907.

² Flint (see bibliography) remarks that there were in 1832 Indian families living in the mountainous interior.

³ Thirteenth Decennial Census (1910).

basis of rural population alone, Porto Rico, with 260 country people per square mile, outnumbers its nearest competitor, New Jersey, by more than 3 to 1, and Rhode Island by 17 to 1. Furthermore, Porto Rico's rural population density alone outranks the total population density of any but the three States mentioned (fig. 5).

The distribution of population in Porto Rico is remarkably even, and the centers of area and population are less than 5 miles apart

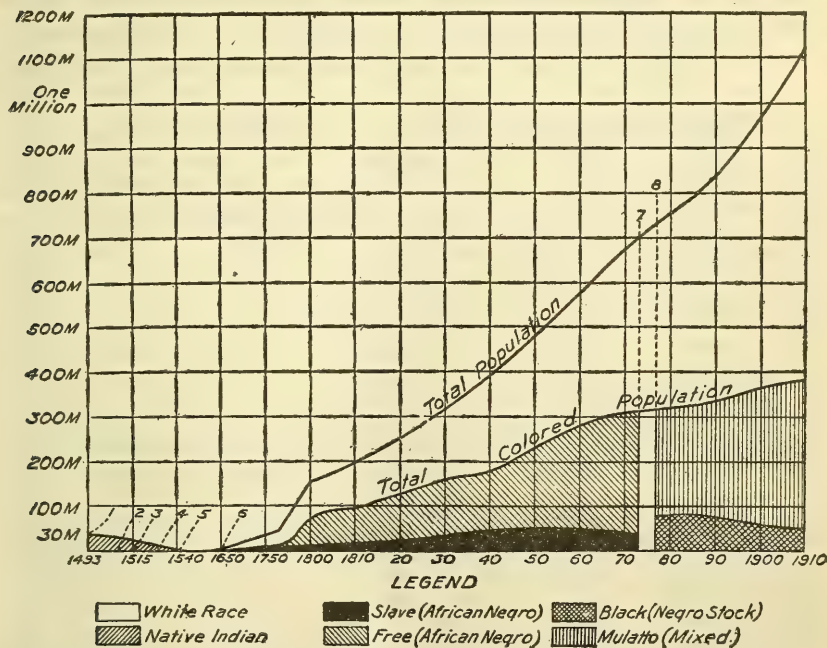


FIG. 4.—Growth in population in Porto Rico.

1. 1493. Island discovered by Columbus. Pre-Columbian population (Fewkes).
2. 1508. First white settlement under Ponce de Leon.
3. 1515. Indians imported from Jamaica and other West Indies in servitude (Fewkes).
4. 1530. First numerical record concerning importation of African negroes (census 1899).
5. 1543. Bishop of San Juan reported to the King of Spain but 60 native Indians remaining on the island (census 1899).
6. Total population middle of seventeenth century, 880 (census 1899).
7. Slavery abolished by act of the Spanish Revolutionary National Assembly, March 22, 1873.
8. Census of 1877 adopted new classification dividing the colored population into "mulattoes" and "blacks," which it will be seen closely conforms to the earlier classes of "free" and "slave" (census 1899).

in a direct line.¹ The center of population lies to the north of the center of the island, because of the more equable climatic conditions, the greater area of arable land, and the location of the capital and largest city, San Juan, on the north side.

¹ The center of area of the island is situated 3 miles north and 2.1 miles west of the town of Barros, and the center of population (1899) was 6.6 miles west and 2.4 miles north of the same town, making the two points distant from each other 6 miles east and west and 4.5 miles north and south. (Census of Porto Rico, 1899).

Occupational statistics show that 33 per cent of the total population¹ are engaged in gainful occupations, and that 62.8 per cent of that number are engaged in "agriculture, fisheries, and mining," the two latter of which are almost negligible.² Almost three-fourths of the men and boys engaged in any gainful occupation are employed directly in agriculture. Literacy is a feature of population statistics which has changed so considerably since the American occupation that but little value attaches to the 1899 figures, which are the latest available. Some idea, however, can be gained by a comparison of the school attendance, which has increased from between 2 and 3 per

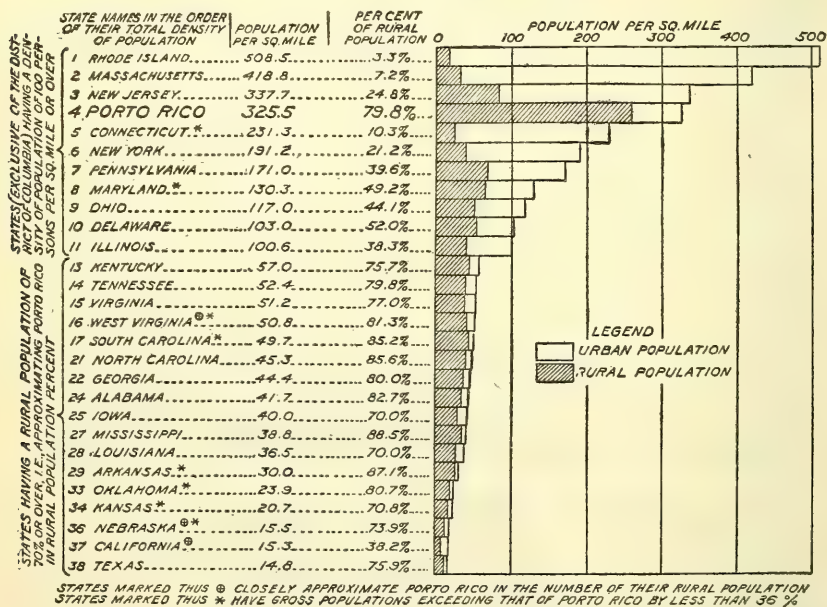


FIG. 5.—Comparative density of populations, showing graphically the relative position of Porto Rico and certain selected States.

cent of the total population during the year following the close of the Spanish-American War to 14.4 per cent in 1912.³ In 1899, of the total population over 10 years of age, only 16.6 per cent could read.

TRANSPORTATION.

The mountainous character of the island, the heavy and unctuous qualities of the soil, and the excessive rainfall conspire to render road building both expensive and difficult, so that until comparatively

¹ This low percentage of persons engaged in gainful occupations is occasioned largely by the abnormally large number of women and of children under 10 years of age, most of whom are enumerated in the dependent class. Thus 30.9 per cent of the total population are children under 10 years of age, and 43.9 per cent under 15 years. (Census, 1899).

² The census of 1899 showed but 455 fishermen and 48 miners or quarrymen on the entire island.

³ Report of the Commissioner of Education (Annual Reports, War Department, fiscal year ending June 30, 1912, Report of the Governor of Porto Rico).

recently roads and other means of travel in Porto Rico have been poor. This confined early settlement and development to the sea-board and delayed the opening up of the interior. Then, too, the products of one section have not been sufficiently different from those in another to sustain an intra-island trade either by land or water. These circumstances and the system of trading which flourished between the West Indies, Europe, and America until recent times made the ports of the south coast, for instance, each commercially closer to Bilboa and Cadiz and to the world ports in general than to San Juan or each other. San Juan in particular, being formerly the last port of call on the voyage to the Old World from Gulf and Caribbean ports, often found it easier to get timbers and other natural products from Santo Domingo than from the immediately adjacent country or a neighboring Porto Rican port. The fact that for over a century Santo Domingan timbers have been in common use in San Juan has led to the belief that Porto Rico was never well timbered or that what large material there was soon became exhausted, whereas the lack of adequate internal transportation facilities offers a more likely explanation.¹

This paucity of transportation facilities persisted until well past the middle of the last century.² The famous military road, the main artery of the projected plan for highways under Spanish sovereignty, was commenced about 1842 and finally completed in 1888, with a total length of 134 kilometers (about 84 miles). The remaining mileage of improved roads, which aggregated 275 kilometers (about 175 miles) at the close of the Spanish régime in 1898, largely comprised isolated sections of several road projects. From the American occupation to June 30, 1912, 794 kilometers (500 miles) of macadam road have been constructed, making a total of 1,069 kilometers (670 miles). These are largely trunk-line roads, from which extend many dirt roads suitable for the bull cart and like vehicles, while beyond these are mountain trails where pack and saddle horses and the land canoe, or flat-bottomed dugout hauled by oxen, are still the only means of transportation.

It is usually only rough mountain trails that reach the "conuco" farmer, the forested area, and many of the coffee plantations. These trails are mostly in very bad condition. Absolutely without drainage,

¹ One can see the effects of similar conditions in operation to-day in Santo Domingo. With 85 per cent of her land area under virgin forests, a sixth of which is pine, Santo Domingo imported from the United States in 1911 forest products to the amount of \$130,800, including 3,937,000 board feet of lumber, valued at \$91,296, and shooks and other unmanufactured timber products, exclusive of naval stores, valued at \$12,206 additional.

² Robin (see bibliography) in 1802-1806 testifies not only to the poor transportation facilities, but to the abundant forests, in the following reference: "The island of Porto Rico is still little inhabited, in spite of the earliness of its settlement. * * * The habitations, isolated and dispersed over the island, lack communication with one another. * * * It is, however, not necessary (in order to provide roads) to cut the mountains, raise the valleys, or fill the marshes, but simply cut down the large and vigorous trees."

the tenacious clay soil, already saturated with moisture, has kneaded into it additional water through the travel of the bulls and heavily burdened pack animals until in places it becomes a semifluid mass resembling thick orange-red paint, often of a depth reaching to a horse's belly. During the dry season, when they dry out on top and crust over, these "baches" are even more treacherous than in their semifluid state, for when a horse breaks through the crust he is the more liable to get mired. Only horses bred to this kind of travel know how to handle themselves under such trying conditions.

For draft purposes in this back country the bull is almost exclusively used. Most of the freighting across the island and into the interior is even now, and on the best roads, done by bull carts, except for a short line of railroad between Rio Piedras and Caguas. Very recently the auto truck and auto stage have been tried in the cross-the-island freight and passenger service, as well as along the coast, and their use unquestionably will be extended.

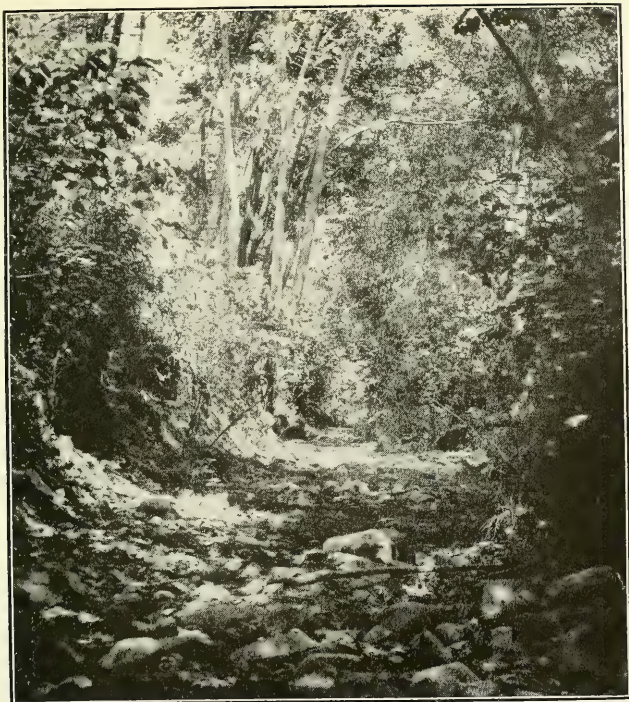
At the time of the American occupation there were 254 kilometers (about 160 miles) of narrow-gauge railroad in operation in the coastal portion of the island. At the present time (1912) it is possible, through the connections established between the various sugar companies' railroads and the original public-service road, almost to encircle the island by rail.

THE FOREST.

The forests of Porto Rico are now so fragmentary and so limited in extent and have been so materially modified by the acts of man during several centuries that they afford of themselves little basis for classification and description. Clearings, severe cuttings, and the culling of the more desirable timbers were noted by the earliest travelers. Then, too, many native species have been transplanted from their natural haunts to others and many introduced species have been brought in and spread over the island. It has consequently been necessary to draw extensively on information from a number of sources and to study the various formations as they have been described in their undisturbed natural state in whatever other part of the Tropics they could be found. In this manner only could a groundwork be obtained for classifying and distributing according to their proper relations the remnants of the once extensive Porto Rican forests.¹

¹ In describing the fundamental features of the various formations the works of Schimper and of Broun particularly have been freely drawn on, and in reference to special features those of Harshberger, of Fernow, and Taylor, and of Woodward (see Bibliography), not to mention the various historical works which have contributed side lights on matters of general distribution.

The work of defining the distribution of formations is a comparatively simple one, because of their close relation to the distribution of rainfall, which latter has been carefully charted by the local Weather Bureau



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FIG. 1.—AN UNIMPROVED COUNTRY ROAD THROUGH THE LOWLANDS.



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FIG. 2.—NATIVE MEANS OF TRANSPORTATION WHICH REQUIRES NO ROADS.
COUNTRY ROAD AND NATIVE TRANSPORTATION.

FORESTED CONDITION AND DISTRIBUTION.

There can be little doubt that Porto Rico was at one time forested from the shores of the Atlantic to the Caribbean, from the Virgin Passage to Mona.¹ Historians, while in general silent as to the extent and character of the forests on the island, have in the aggregate left a considerable collection of data concerning the subject,² sufficient it would seem, together with present-day indications, to bear out the contention of a once completely forested Porto Rico.

One has but to turn to the neighboring islands of the Greater Antilles, which are closely related both geologically and botanically, if further corroboration of Porto Rico's original forested condition is required. This close relationship and similarity even down to such details as common names is strikingly brought out by a comparison of the description by Fernow and Taylor³ of the Sierra Maestra in Cuba, by Woodward,³ of the Santo Domingo forests, and by Gifford,³

office. Slight departures only are necessary to make allowance in certain cases for the influence of the limestone soils. Altitudinal differences are so slight as to have comparatively little effect.

In the descriptions local names, wherever possible, have been adhered to, and following each such name is a number in parentheses, thus, guaraguao (74), which number refers to the specific description in Appendix I, "The Trees of Porto Rico."

Whenever desirable, a brief paragraph in small print concerning the chief features of the same or a closely related formation in other parts of the Tropics follows the description of the local Porto Rican formation. Thus it is hoped that interest in the forest will be heightened through comparison and that the way may be opened for the judicious selection of new species to be introduced into Porto Rico.

¹ The following from a letter from Mr. Alex. Wetmore, assistant biologist, Bureau of the Biological Survey, U. S. Department of Agriculture, who recently completed an exhaustive study of the bird life of the island, is of considerable interest in this connection: "On examining the endemic species of Porto Rican birds, I find that with one or two exceptions they are forest-inhabiting forms, pointing thus to a very extensive forest area on the island. The forms as differentiated here must have inhabited such an area during the period of evolution, and species with a preference for open savannas may have come in later, or may have been very few in number until within historical times. The extensive area of moist deciduous and tropical rain forests shown by you on the forest-distribution map, all point to this hypothesis."

² Oviedo, writing of the early years of 1500 concerning animals, trees, and the like in Porto Rico, stated that they did not differ from those already described in the "Isla Espanola." The North American and West Indian Gazetteer (1778) states that "the sides of the hills are covered with trees of various kinds, proper for building ships and other useful purposes." Fray Iñigo (1788), besides mentioning the superior and much greater variety of timber trees in the uplands, also states that many trees are found in the southern part of the island as well, although conditions there were much more arid and less fertile than on the north coast. In the account of the capture of San Juan by the Earl of Cumberland (1597), the small island on which San Juan is situated is described as "for the most woods." Continuing, the Luquillo region and the interior generally are described as follows: "The valleys are much wooded but in very many places interlaced with goodly large Playnes and spacious Lawnes. The woods are not only underlings but timber trees of goodly tallnesse and stature, fit for the building of ships and of every part of them." According to Herrera, (English translation, 1726), "The Island * * * has much good pasture for cattle, which decreases, by reason of the great number of trees increasing * * * so that the Island is overgrown with Woods." Flinter (1834), speaking of the surroundings of Guayama, says that 5 or 6 years previously it was merely "an immense tract of woodland." He also says: "The forests which cover the mountains of Porto Rico are filled with timber of the best quality for the construction of ships and houses. In some parts of the coast from the very improvident manner in which wood has been cut down and burned for charcoal and much left to rot on the ground, timber is getting scarce; but in the interior there is yet an abundance of superior timber." In 1830 timber to the value of \$21,000 was exported through the customhouses of this island, exclusively of what is shipped clandestinely." This work in particular has numerous other references to the extent and luxuriance of the forest growth on the island. Finally Barrett (1902) tells us that "more than half a century ago the Spanish planters of the island began clearing the interior districts for coffee and tobacco culture. There being no good roads and but little demand for timber, the trees were burned where they fell; hundreds of thousands of dollars' worth of lumber and cabinet woods were thus destroyed."

³ See Bibliography.

of the Luquillo. The forests of Porto Rico differ from those of the other islands chiefly in the absence of any pine growth. Santo Domingo, now least changed from its original pre-Columbian condition, still has fully 85 per cent of its land area under virgin forest. Probably at least 50 per cent of Cuba is wooded, not far from 30 per cent being virgin forest. Santo Domingo has a population density of 33 per square mile, Cuba 46, and Porto Rico 325. There is little wonder that Porto Rico is nearly deforested.

The assertion of a completely forested Porto Rico does not mean that there were no open lands at the time of Columbus's first visit. There were in fact even then more or less extensive clearings surrounding each native village. These clearings were continued and extended by the white settlers that they might cultivate sugar cane, ginger,

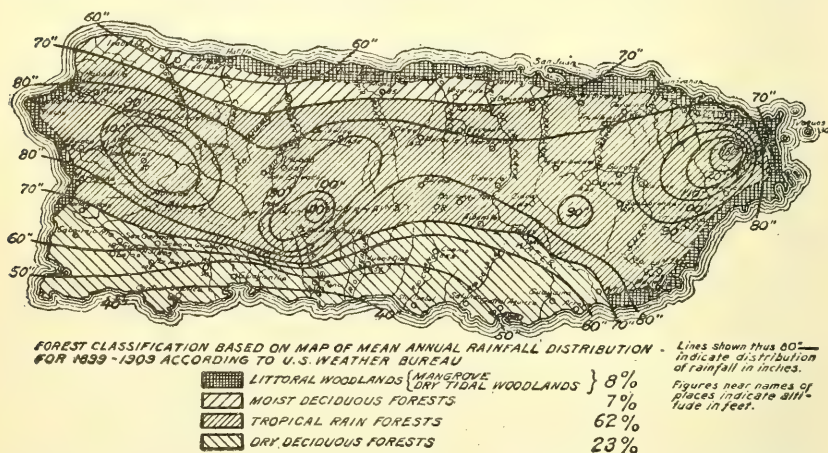


FIG. 6.—Porto Rico. Pre-Columbian distribution of forest formations. (Diagrammatically shown.)

and other crops, and provide pasture for cattle brought from Spain. The clearing proceeded more rapidly on the north than on the south side of the island and was likewise confined for the most part to the lowland. Until nearly the middle of the nineteenth century the interior mountain forests were probably but little disturbed. The gradual ascendancy of the coffee industry over that of sugar and tobacco, which culminated during the closing years of Spanish rule, undoubtedly strongly influenced the development of the interior.

Of the once extensive virgin tropical forest there now remain only isolated remnants scattered over the island in its most mountainous parts. The best known and most famous of these, and the largest as well, still covers a considerable portion of the Luquillo Range. While it has for upward of half a century been gradually encroached upon, progress has been slow. The abruptness of the slopes and the size of the trees have made timber exploitation by native methods

very difficult. Exposure to excessive and constant strong winds, abnormally heavy precipitation, and extended cloudiness have prevented the region from being invaded to a greater extent by the coffee planter. These same conditions also have doubtless not been entirely to the liking of the "conuco" farmer, at least so long as there were other lands available. This tract has an aggregate acreage of between 35,000 and 40,000 acres, including several thousand acres of low gnarled growth on its summits and wind-swept slopes. A part at least of this forested area is in government ownership.

Other tracts, more or less limited in extent, of virgin or only lightly culled high forest are to be found near Maricao, in a deep ravine at the headwaters of the Rio Maricao, near Jayuya, on Mount Morales and Mount Mandios;¹ near "La Isolina" on the Rio Limon between Utuado and Ciales;² and in Barrio Angeles between Lares and Utuado on the Rio Angeles.³ The aggregate of all such areas, aside from the Luquillo, is believed to be well within 5,000 acres, making the total area of high forest scarcely 2 per cent of the total land area.

There are besides about 400,000 acres assessed as "timber and brush lands" and a few thousand acres additional classified as swamps and largely under mangrove. Of the timber and brush areas the bulk will be found in the southern, southeastern, and southwestern parts of the island, on the dry limestone hills and other land of little or no agricultural value. On the north side such areas will be found almost exclusively on the thin-soiled, conical limestone hills.

Thus, including virgin forests and all, the total wooded area amounts to approximately 20 per cent of the total land area. In all probability not more than from one-fourth to two-fifths of this area (5 to 8 per cent of total land area) is now under forest capable of yielding a wood product other than charcoal and fuel wood. If now there be added the 168,000 acres in coffee plantations and the 6,500 acres under coconut palms which are in effect artificial forests, the grand total of all lands under a forest or brush cover will approximate 600,000 acres, or 27 per cent of the insular domain.

FOREST FORMATIONS.

The term "virgin forest" was formerly applied by travelers in the Tropics exclusively to the evergreen forest found in constantly humid regions or those of similar luxuriance along the watercourses; in other words, to the tropical forest jungle. Not only are these not

¹ Reported by N. L. Britton in *Journal N. Y. Botanical Garden*, May, 1906.

² Reported to the writer personally by the director of the U. S. Weather Bureau at San Juan and by L. M. Underwood in *Journal N. Y. Botanical Garden*, Nov., 1901.

³ Reported personally to the writer by the lieutenant of police at Utuado.

the only virgin forests in the Tropics, but in many cases they themselves may not be virgin at all, but second growth.¹

Because the rain-forest—the jungle—presents not only unusual but often spectacular features which make a most direct appeal to the interest and a most lasting impression on the mind, it has come to typify the tropical forest in general. Yet it would be scarcely less misleading to represent the mammoth redwoods or the giant fir and cedar forests of our Pacific coast, or even the magnificently diversified hardwood forests of the Appalachian region, as being the typical and prevailing forest growth of temperate North America.

In its original forested condition Porto Rico undoubtedly presented a diversity of forest formations unexcelled in any other similar area in the West Indian Tropics. Of the general types found throughout the Tropics, only those were impossible of occurrence which result from extremes of altitude and of drought. Thus alpine and desert elements were unquestionably never developed here. The various formations in the order of their occurrence from the coast toward the interior are as follows: Littoral woodlands, moist deciduous forests,² and tropical rain-forests on the north or humid side, and the dry deciduous forest³ on the south or semiarid side.

The distribution of these formations was, of course, not so simple as might be implied by the last sentence, there being more or less overlapping. Remnants of these formations are, with few exceptions, still to be found in the out-of-the-way places of the island, although their original balance and relative importance have been very much modified.⁴

¹ This is very interestingly brought out in Cook's "Vegetation Affected by Agriculture in Central America" (Bureau of Plant Industry Bulletin 145), from which the following is quoted: "Many localities which are now occupied by apparently virgin forests are shown by archaeological remains to be regions of reforestation. Thus in the Senahu-Cahabon district of Alta Vera Paz, relics of two or three very different types of primitive civilizations indicate that as many ancient populations have occupied successively the same areas which are now being cleared anew by the coffee planters as though for the first time.

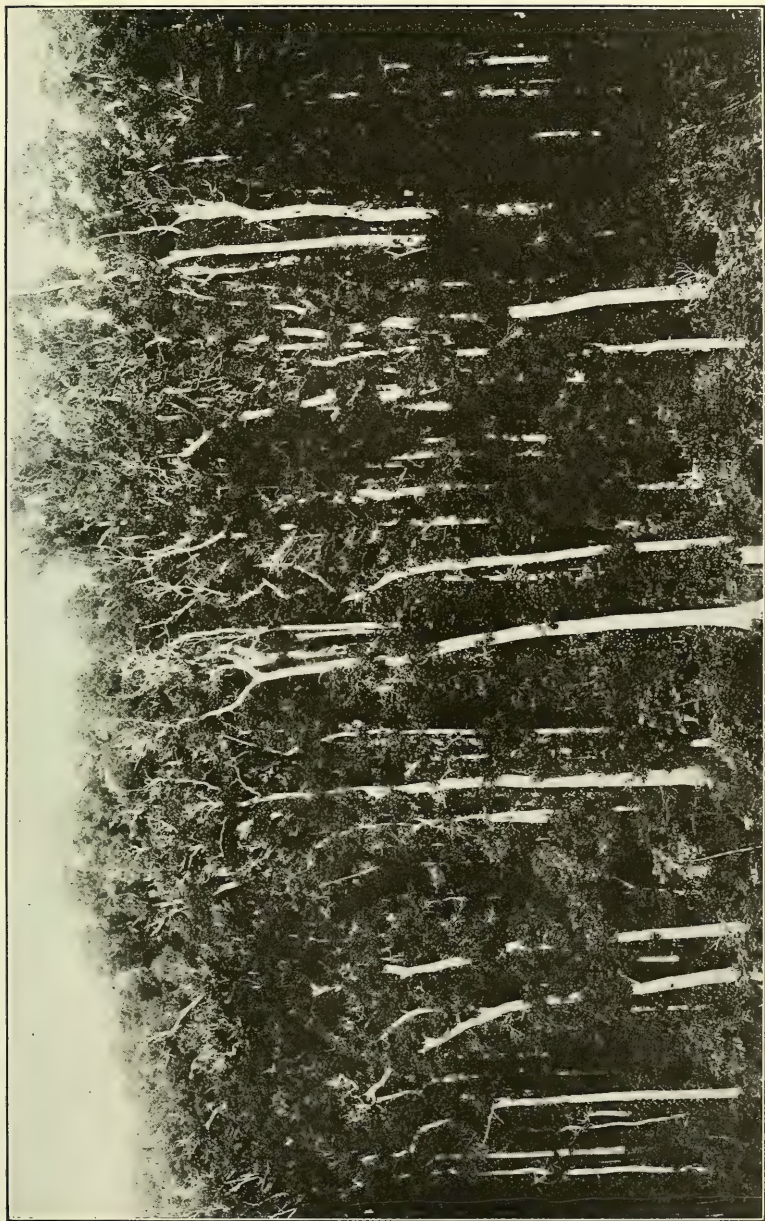
"It does not yet appear that any considerable region of forest has been explored in Central America without finding similar evidence that the present forests are not truly virgin growth. * * *"

And again, speaking of the evidence of antiquity as exemplified by the crumbling of large earthenware pots of an earlier civilization, he continues: "We can not know how long it has taken the pottery to crumble, but we can at least contrast the condition of these decayed pots with other pieces of pottery placed in caves of the same district in later prehistoric ages, which will appear fresh and new, as though recently burned. And yet the bones beside these apparently new pots have also crumbled nearly to dust, and there has been time for the surrounding country to be occupied with old forests of hardwood trees, like true virgin growth." He also mentions terracing of the land as showing that agriculture was formerly extensively practiced and notes the presence of a type of terrace evidently designed "to hold drainage water and prevent erosion * * * being frequently met with in the heavily forested region of eastern Guatemala."

² Called "monsoon forest" by Schimper.

³ Also called "thorn-woodland" by Schimper and "chaparral" by Harshberger.

⁴ The natural balance and relative importance of the different formations as given by Woodward for Santo Domingo on a percentage basis for the total forested area is as follows: Wet hardwood type (which includes the "moist deciduous" and "tropical rain" forests of the above classification), 58 per cent; dry hardwood type ("littoral woodlands" and "dry deciduous" forests), 28 per cent; pine type (lacking entirely in Porto Rico, but occurring on a similar site to the "dry deciduous" forest), 14 per cent.



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VIRGIN STAND OF TABANUCO. MOIST DECIDUOUS FOREST FORMATION NEAR LA ISOLINA (ARECIBO).

LITTORAL WOODLANDS.

The littoral woodlands, although most characteristically developed on the humid side of the island, have certain strong resemblances to the dry deciduous forests of the south coast, the one merging into, giving way to, or overlapping the other at their points of contact. Both formations are forced to struggle continually against the effects of drought. In the case of the littoral woodlands this is occasioned largely by porous and saline soil conditions accentuated by certain adverse climatic factors, strong wind particularly. With the dry deciduous forests, the determining factor is deficient rainfall, to which adverse soil conditions give added effect. The littoral woodland formation presents two distinct types, namely, the mangrove or wet tidal woodlands below high-water mark and the dry tidal woodlands above high-water mark.

THE MANGROVE.

The mangrove, or wet tidal woodland, is a distinctly tropical formation. Though unable to withstand unbroken wave action on the open coast, it readily establishes itself in the shallow brackish waters of protected embayments, creeks, and lagoons, where, under favorable climatic conditions, it forms dense, almost impenetrable thickets. The Porto Rican mangrove rarely attains a height of over 10 feet above the water, though elsewhere it reaches very respectable forest dimensions. Even in the more or less protected lagoons it is generally exposed to the strong trade winds, which accounts in part for its low stature, while its popularity for fuel and other uses undoubtedly prevents it from attaining its full size.

The sea, receding at low tide as far as the edge of what seems at high tide a veritable forest rising from the waters, reveals a tangled mass of stiltlike roots anchoring the trees to the blue-black muck along the shore. With every tide new soil material is deposited among the mangrove, which keeps gradually pushing out to occupy new ground, through its remarkable mode of reproduction. The fruit when it reaches maturity remains attached to the parent plant, the seed embryo all the while continuing its development into a new young plant. Having attained a certain size this plant releases itself, falls into the soft mud, strikes root, and becomes firmly fixed within a few hours.

The mangrove in general attains its most favorable development where the humidity is high, precipitation abundant, and an intermittent cloudiness prevails. Its distribution accordingly coincides in general with that of the rain-forest.¹ Thus the mangrove in Porto Rico is most abundant along the north and east coasts, is much more restricted on the west coast, and is only sparingly and locally de-

¹ See Schimper's Plant Geography.

veloped on the south. Here it occurs chiefly at the mouths of the larger rivers, where a dilution of the sea water enables it to grow in spite of the otherwise unfavorable climatic conditions.

Three of the four common species of the western mangrove,¹ of tropical American and West African coasts, occur in Porto Rico. One is known locally as mangle colorado (122),² and the other two as mangle blanco (or bobo) (127 and 157). Mangle colorado occupies the outer exposed edge of the formation, while mangle blanco occur, the one (*Avicennia*) intermediately and the other (*Laguncularia*) at the inner boundary. The latter often forms pure mangrove. Other species associated with this formation are mangle botón (125) and mangle prieto (unidentified), small trees, usually under 20 feet in height. On drier islets within the formation other species may occur, and likewise on the inner side, where by a gradual transition the mangrove gives way to the dry tidal woodlands. Epiphytes, so characteristic of other tropical forest formations, are scarce and are confined to a few bromeliads and lichens.

The mangrove is of considerable economic importance, furnishing fuel, especially to the bakeries, from its limbs and branches, and posts and house piling from the submerged parts. For these latter uses it is very highly prized because of its resistance to decay and to the attack of the white ant. The bark contains a tanning material and a dye, though to what extent it is used locally is not known.

Practically all of this mangrove land belongs to the insular government. In a few places, as in parts of San Juan Harbor, the mangrove will have to be cleared away to make room for needed water-front improvements. Other tracts might perhaps be converted into arable land by drainage. Most of these lands, however, should be retained by the government and managed under approved forestry principles as public wood reserves.³ They would constitute a most valuable

¹ The fourth species, *Avicennia tomentosa* Jacq., is not identified from Porto Rico. The eastern mangrove is much richer in forms. Thus in Farther India and the Malay Archipelago, where it shows its greatest diversity, it consists of Rhizophoraceæ (9 species), Lythraceæ (3 species), Combretaceæ, Meliaceæ, and Verbenaceæ (2 species each), Myrsinaceæ, Rubiaceæ, Anthraceæ, and Palmæ (1 species each); 22 species in all, according to Schimper.

² The figures in parenthesis refer to the descriptive list (Appendix I).

³ In many eastern tropical countries the immense value of these swamp areas is now fully appreciated. In the Federated Malay States the mangrove is classed as "one of the two important divisions of the commercial Malay forests." In 1904 the development of the mangrove areas as a source of fuel supply for the Government railways and for general public consumption was begun under systematically prepared working plans. (Burns-Murdock, A. M. "Notes from the Federated Malay States," Indian Forester, Vol. XXX, No. 10, Oct., 1904).

In the Philippines the mangrove is regarded as "in many respects one of the most valuable forest assets of the islands." The bureau is now engaged in selecting the most important commercial areas and thoroughly investigating their possibilities. (Director of Forestry of the Philippine Islands, annual report for fiscal year ending June 30, 1912).

The mangrove is managed on a short rotation under a clean-cutting system, making it a simple crop to handle. As practiced by the Philippine natives in growing "bacauan" (includes several mangrove species) for cordwood, the seed is collected and sown at a cost of about \$2.50 an acre. Then without any further attention the crop at the end of six years is ripe to cut, and brings as high as \$20 an acre on the stump, according to W. D. Sterrett, formerly forester of Bataan Province, Philippine Bureau of Forestry.

source of cheap wood supply for general use, where it is most needed, in and around the coast cities, and would yield a considerable income to the government through the sale of the wood and other products.

DRY TIDAL WOODLANDS.

The dry tidal woodland is confined to the sandy or gravelly soil areas skirting the open shore or lying directly behind the mangrove type in the sheltered embayments. While its former extent and distribution can be reasonably well defined, its original composition can only vaguely be surmised. Its sole representatives at the present time are groves of coconut palm; the dry deciduous forests of more or less strongly modified composition, due to the intermingling of typical shore species such as uvero (14) and others; and the open shrub growths of these latter species alone.¹ The coconut palm type will be considered in more detail elsewhere as will also the dry deciduous forests.

EASTERN LITTORAL WOODLANDS.

The littoral woodland is readily distinguishable in the East Indies and adjacent continental areas, where it has been more or less carefully studied and described, particularly in Java. At present two of the most conspicuous trees planted in and around San Juan are from this formation, the almendra (123) and the more recently introduced *Casuarina equisetifolia* (Australian beefwood). Other characteristic treespecies of the eastern littoral are *Cycas circinalis*, *Pandanus* (several species), *Calophyllum inophyllum* (Guttiferae), *Cerbera odollam* (Apocynaceae), *Hibiscus tiliaceus* and *Thespesia populnea* ("Emmajagua" and "Santa Maria," respectively, of Porto Rico), (Malvaceae), *Hernandia peltata* (Hernandiaceae), *Heritiera littoralis* (Sterculiaceae), and various Leguminosae (*Inocarpus edulis*, species of *Albizzia*, *Cynometra*, *Erythrina*, *Pongamia glabra*, *Sophora tomentosa*, and others).

MOIST DECIDUOUS FORESTS.

Transitional between the littoral woodlands and the rain-forest formations in all probability originally occurred the moist deciduous forests. On the north side of the island this formation occupied the limestone belt lying between the coast and the central mountains and extending from San Juan west to Aguadilla. On the south side it very likely was confined largely to the middle and upper south slopes of the central mountain clay soils. Little forest growth of any sort, however, now remains on these areas. Particularly is this true of the south slopes of the Cordillera Central, where the trees are scattered

¹ The failure of plant geographers to recognize and segregate this information in the West Indies is probably due to the fact that the sites where this formation had formerly attained most characteristic development have long been exclusively appropriated by man for the cultivation of the coconut palm. Elsewhere, possibly by cutting and the more aggressive competition on the part of the closely allied dry deciduous formation, its composition has been so modified as to make these two formations scarcely distinguishable one from the other.

singly or in small clumps on the open grass slopes and in narrow strips along the watercourses.¹

On the north side of the divide the virgin forest area near La Isolina constitutes a possible remnant of this moist deciduous forest. Here the tabanuco (69) is a prominent feature in the stand. Elsewhere, as on the limestone uplands north of Lares, the moralon (15), aceitillo (66), capa blanca (155), limoncillo (129), granadillo (124), and other large trees are reported formerly to have been common. Here, too, we should expect to have found the caoba (72). Some of the rich forest growth was cut for fuel and building material, but much of it is reported to have been cleared away by the "conuco." The land here is now merely open grass land.

In the "pepino" or "pit" country a homogeneous forest cover is impossible. In the pit bottoms, which are now largely under cultivation to bananas and coffee, a high forest cover of the moist deciduous type undoubtedly prevailed. The steep sides and summits of these hills in many places even to-day present a well-wooded appearance, though the occurrence of an occasional fair-sized tree in some particularly inaccessible place throws into contrast the main cover, which is low and bushy and much like that of the dry deciduous formation. Undoubtedly these rough crags have been cut over in the past, but owing to their absolute uselessness for cultivation they have escaped being burned over.

EASTERN MOIST DECIDUOUS FORESTS.

The moist deciduous formation of India and Ceylon contains most of their valuable timber trees, such as teak (*Tectona grandis*), sal (*Shorea robusta*), satinwood (*Chloroxylon swietenia*), ebony (*Diosypros ebenum*), trincomalie-wood (*Berrya ammonilla*), etc. Near the coast a number of evergreen trees are found in mixture, as *Mimusops hexandra*, *M. elengi*, species of *Memecylon*, *Pleurostylia wightii*, *Nephelium*, *Sapindus*, etc. In Australia this is a savanna forest and consists largely of acacias and eucalypts.

In South America this formation more closely resembles the savanna than the rain-forest type and is known locally as "campos," "llanos," "caatinga," etc. It is important economically because of the rubber-yielding trees which grow within it, the "ceara-rubber" tree or "manisoba" (*Manihot glaziovii*, *M. dichotoma*, *M. piyauhensis*, etc.) and the "para-rubber" tree (*Hevea braziliensis*), the former in the open savanna forests of northern Brazil and the latter in the basin of the Amazon.

TROPICAL RAIN-FORESTS.

Forest vegetation culminates in density and luxuriance of growth in the rain-forests, the most extensive of the original forest forms,

¹ *Fringing-forests*.—Closely allied to both the moist deciduous and rain-forest formations are the appropriately named fringing-forests or gallery-forests, mentioned, respectively, by Schimper and Broun, dense tropical forests of unusual luxuriance occupying the banks of streams and rivers within dry regions. They owe their luxuriance to the abundant moisture in the soil. Their extent back from the river thus depends on the quantity and constancy of the stream flow and the modifying influence it is able to exert on the adjacent soils. Such was the type of forest in all probability that Flinter (see note, p. 21) referred to particularly as occurring in the vicinity of Guayama. Remnants of these forests are to be seen to-day, in many places bordering the south coast streams where they have not been destroyed to make way for cane growing. The contrast between them and adjacent forests of the dry deciduous formation is very striking. The rich forests of the Amazon are to a considerable extent of this type.



F-19760A

FIG. 1.—SECOND GROWTH MOIST DECIDUOUS FOREST BETWEEN ISABELLA AND QUEBRADILLAS.



F-19757A

FIG. 2.—“FRINGING FORESTS” WHICH SKIRT THE WATER COURSES THROUGH THE SEMIARID SOUTH COAST REGIONS, YET EXHIBIT MANY OF THE CHARACTERISTICS OF THE MOIST DECIDUOUS AND RAIN-FOREST FORMATIONS.

TYPES OF FOREST.

formerly covering the entire central uplands of the island, including the valley plains of the large rivers, and reaching quite to the coast on the east and west ends of the island. They undoubtedly attained their richest development in the bottoms and sheltered slopes of the larger river basins, but these being the most productive and the most accessible, were the first to be stripped of their forest wealth. There is little doubt that the greater part of this splendid natural resource was never utilized, but was felled and burned. What remains is but a poor example of this once magnificent forest domain.

The rain-forest from a distance looks not unlike our northern deciduous forests, except where groups of palms or the yagruma (136) occur in mixture with the broadleaf trees or where the bright-colored blossoms of some flowering tree or epiphytic plant perched high in the crown of its towering host interrupts the green of the background. The foliage presents a variety of the duller and more somber greens, but lacks entirely the fresh new green of the spring foliage in the north. The crown level is also less regular than that of our northern woods. Individual trees with wide-spreading crowns tower far above the general level, the whole presenting a jagged and haphazard appearance. On closer inspection a further contrast is apparent in the greater number of trees with compound leaves, such as cedro (71), guaraguao (74), and many others. The crown of the average tree of the rain-forest is very much less branched than that of the northern deciduous forest tree, there being but few main branches, themselves only slightly branched, so that the tree has a very irregular appearance. The leaves are highly diversified, not infrequently glossy, and of a fine leathery texture, and though pinnate seldom finely so or felted with hairs. They are usually set obliquely with relation to the direct overhead light and often aggregated in tufts at the ends of long, bare branches.

The interior of the rain-forest is still more striking in contrast and more haphazard in appearance than its exterior. The growing space appears to be unequally utilized; in places the stand is very dense and is matted and tangled with a profusion of thick-stemmed woody lianas and countless epiphytic orchids, bromeliads, ferns, and even trees; covering every branch and extending to the tops of the tallest trees; in other places the cover is very much broken, permitting great patches of sunlight to reach the ground. In the denser parts the ground is very sparsely covered, while in the openings palms and other young trees, or a most detestable cutting grass, strive to occupy the ground. True shrubs are inconspicuous, most of the undergrowth being of the same species as the main forest cover.

The soil in the forest is not only in large measure bare of herbaceous growth, but it is very poor in vegetable mold. It is simply blackened by the decaying vegetable matter. Humus, as we know it in the

broadleaf forest of the the north, is very rare. Decomposition is extremely rapid under the influence of tropical heat and great humidity, and these, together with more gradual leaf fall, extending over the entire year, prevent the accumulation of litter. Then, too, the torrential rains wash much of it off the steep slopes almost as rapidly as it is formed.

As to the trees themselves there is almost infinite assortment of kinds, sizes, and forms. One of the most striking features is the large number of light-colored, smooth-barked species resembling in appearance our northern beech.¹ Then, too, the trunks of the trees forming the main crown cover are very characteristic, being for the most part of very unequal thickness, and usually more slender² than those in the virgin forests of the Temperate Zone. Large trees up to 5 feet in diameter above the root flare, however, are not lacking even to-day in the Luquillo. There are, besides, many trees, tabanuco (69) for instance, with a much-buttressed base formed by planklike outgrowth from the trunk and the uppermost roots.

There is a striking lack of uniformity in association and in distribution of species. The reasons for this are the vast number of species,³ the combination of accidental association that such a number makes possible, and the absence of any considerable modifying soil or other conditions tending to form fixed associations within the broader and more uniform climatic one.⁴ The presence or absence of a tree, particularly one of the more valuable kinds, like cedro, appears to be a matter largely of chance. The really valuable trees seem almost hopelessly in the minority, while the inferior species are so numerous as to impress one with the apparent worthlessness of the forest. Unquestionably many of the so-called worthless woods are unjustly

¹ According to Schimper this is owing to the prejudicial effect of humidity on the formation of cork, the bark thus remaining poorly developed. The formation of bark is often so poor that moderately large trees show green, owing to the chlorophyll of the cortical layer being visible through it. There is, nevertheless, considerable individuality to the bark of different trees; some have thin flaky and scaly bark, as in Myrtaceae, or a green surface, as in some Leguminosae; others, again, are armed with spines or corky warts, while still others exude resins when wounded.

² This, according to Schimper, is a distinguishing characteristic of the virgin tropical forest. Woodward, too, discussing the rain-forest in Santo Domingo, states that while trees over 5 feet in diameter and 100 feet high are occasionally found, the average is far below these figures.

³ Gifford and Barrett in their "Trees of the Luquillo Region" (appendix to Bulletin 54, Forest Service, "The Luquillo Forest Reserve, Porto Rico") compiled a classified description of something over 100 identified species and enumerated besides the common names of nearly 100 more.

⁴ That the condition is not peculiar to Porto Rico, as many believe, and that, except in extent, the rain forests of the Luquillo do not essentially differ from the other Antillean forests, the following will show: Woodward remarks that in the virgin rain-forests of Santo Domingo two caoba (mahogany) trees to the acre constitute a good stand. Fernow, likewise, is speaking of the virgin forests of the Sierra Maestra, Cuba, remarks that it was most puzzling to discover a law of distribution. "After many days cruising," he says, "over canyon, slope, and ridge one finds in identically the same kind of locality a new species, a single tree or group never to be seen again in further cruising. Nearly 400 miles had been traveled before the first group of ebony was met." He further states that "the openness of the main stand may be judged from the statement that as developed by some 1,200 acres of sample area, less than 1.4 trees of commercial size per acre were found. When it is considered that over 100 species participate in making up this stand the difficulties of a commercial or even a botanical survey will be realized."

discriminated against because their good qualities are commercially unknown.

There is an almost complete absence of species having a gregarious habit, the tabanuco (69)¹ and palma de sierra (3) being the chief exceptions.

RAIN FORESTS OF THE LUQUILLO.

The entire forested area in the Sierra de Luquillo is within the rain-forest belt. The situation is, however, a generally unfavorable one as compared with other areas of abundant rainfall by virtue of its unshielded exposure to the full force of the trade winds, so that the forests here represent rather the minimum tropical rain-forest development.

The main stand of the typical rain-forest development previously described covers probably somewhat more than half of the mountain area. Its four leading species are tabanuco (69), guaraguao (74), laurel sabino (17), and ausubo (141), in the order of their numerical importance. Largely because it has always been in great demand among the natives for all manner of uses, the ausubo is now quite scarce. Cedro (71), too, is only occasionally to be found here. It is doubtful if there was ever more than a scattering of caoba (72), because of its preference for a slightly less humid site. While these forests are usually considered to be undisturbed original growth, such is not, strictly speaking, the case, for cedro and others of the more valuable woods have been taken out a tree at a time by a gradual culling process extending over many years.²

Two subordinate types within the tropical rain-forest belt of the Luquillo are the "hurricane hardwood" and "sierra palm" types. The former, occupying the places of greatest exposure, the ridge summits and the easterly slopes above 2,500 feet elevation particularly, is a low, gnarled, and stunted tree growth, mainly of the inferior species.³ Scarcely 25 feet high, the stands are in most places very dense and the limbs of the trees interlace and are covered with water-laden moss. For days at a time this type may be continuously bathed in

¹ See Plate III.

² There is authentic information concerning one cedro cut within the last 6 years from the south side of the range, the stump of which yet remains and measures 18 feet in circumference ($5\frac{1}{2}$ feet in diameter). Several attempts are reported to have been made before a purchaser could be found for this tree because of its size and the difficulty of felling it and moving it away with the ordinary means at hand. Another, still standing at the present time, measures 25 feet 5 inches in circumference.

³ An instance called to the attention of the writer relative to one of the secondary peaks visited by him in 1912 toward the south side of the range (elevation 3,000 feet) suggests the possibility of the hurricane of 1898 being at least a contributory cause of the low cover found on these exposed sites and led to the selection of the name "hurricane hardwood" type to designate this growth. An American resident said that at the time she took up residence there in the winter of 1899-1900 this peak was stripped entirely bare of all vegetation and that it remained so for 2 to 3 years afterward. Gradually it showed patches of green and eventually became entirely covered. The present stand is a dense young growth of yagrumo, palma de sierra, and other of the poorer quality hardwoods. It may be significant that Dr. George Eggar, quoted by Hill, does not remark on the presence of such a growth at the time of his exploration of El Yunque in 1887, when a more normal growth may have been present.

moisture by the clouds, which leave the summits of these mountains only intermittently during a considerable part of the year. Although commercially of no value whatever, this scrub growth is tremendously important in protecting the exposed slopes from erosion.

Palma de sierra occurs throughout the uplands and in places in sufficient numbers to dominate the stand, forming what may be called the "sierra palm" type. This occurs alike on the exposed easterly slope and in the protected basins, often where the land is rough and stony and windfall most likely. Consequently it is quite likely a temporary type brought about through windstorm or other accident to the original stand. In the protected localities the associated species comprising the more valuable hardwoods are numerous and usually well developed, so that the growth is not without commercial value and future possibilities. At present these two types—the "hurricane hardwood" type, of no commercial value, and the "sierra palm" type, only partially merchantable—aggregate about half the forested area and dominate the mountain tops and exposed uplands of the Luquillo.

RAIN FORESTS OF THE EASTERN TROPICS.

Many valuable species, including the great natural order of the Dipterocarpaceae, find their homes in the luxuriant rain forests of the Philippines, the other East Indies, and the neighboring mainland. The different trees of this order by the variety of their woods, varying from those resembling our soft pine to the heaviest and hardest cabinet woods, are suitable to almost every conceivable use. Several are gregarious and form more or less pure forests, as for instance the eng (*Dipterocarpus tuberculatus*) of Burma, the hora (*D. zeylanicus*) of Ceylon, also *Vatica obscura* and *V. roxburghiana* of Ceylon. Other forests are dominated by members of this natural order. Thus, in the moister forests of Ceylon there are portions composed almost entirely of different species of *Doona*, freely mixed with *Dipterocarpus*, *Shorea*, *Stemonoporus*, *Hopea*, and along rocky gullies *Vateria*. In the Philippines 70 per cent of the total stand of timber is said to consist of trees of this family. Economically, therefore, this natural order is a very important one, for besides its major timber products it yields many valuable minor products, as camphor from *Dryabalanops aromatica*, gum resin and dammar from several species of *Shorea*, *Doona*, and *Dipterocarpus*, and so on. The tribe of the bamboos also finds in these wet tropical forests its greatest development.

Besides the above there are many species of value both in the East Indies and on the mainland, in Africa, and tropical Australia and Queensland. This region, not to mention the resources of tropical America, affords opportunity for almost infinite selection for introduction by which to repair any deficiencies in commercial qualities of the Porto Rican tree flora.

DRY DECIDUOUS FORESTS.

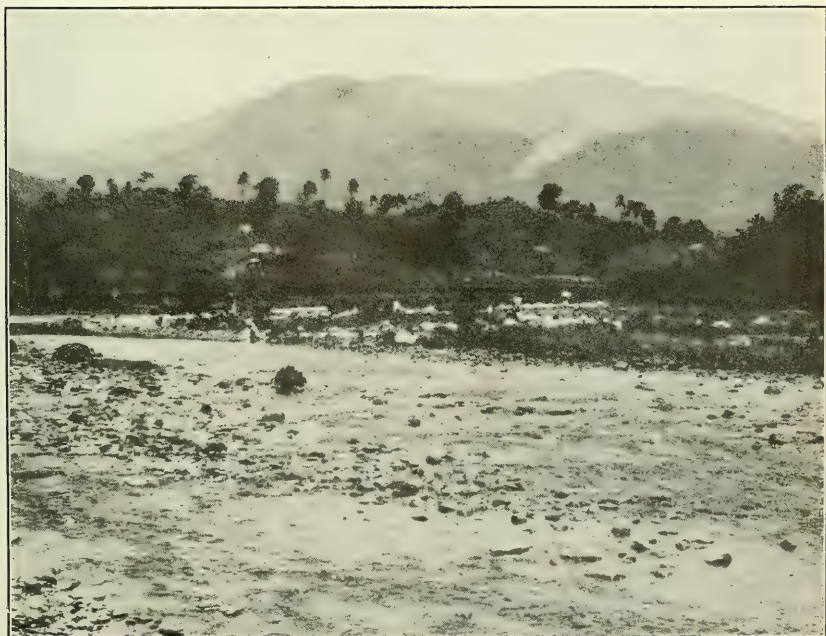
The dry deciduous formation known in others of the West Indies and in Central America and Mexico as chaparral was in pre-Columbian times the second most extensive. Typically a formation of the semiarid region, it dominated the south coast lands, foothills, plains, and lower slopes of the central mountains from Patillas to Hormin-



F-19762A

FIG. 1.—SOUTH SLOPES OF LUQUILLO MOUNTAINS.

Cleared almost to the summit. "La Florida," the fruit farm in the foreground, is in the southeast corner of the Forest on the Rio Blanco. The elevation here is about 100 feet while the peak in the background, scarcely 2 miles distant, is 3,000 feet above sea level.



F-19759A

FIG. 2.—LUQUILLO MOUNTAINS FROM THE NORTH.

Valley of Rio Maneyes in foreground. El Yunque, elevation 3,483 feet, at the right. Smoke in the middle ground probably from the burning of cane refuse after the harvest.

LOQUILLO NATIONAL FOREST.



F-19761A

FIG. 1.—THE WOODED SUMMIT OF EL YUNQUE, FROM LAS PIEDRAS, A ROCK BALD CLOSE TO THE SUMMIT.

Note the sierra palms mixed groupwise in the hardwood stand.



F-20022A

FIG. 2.—VIEW TO THE EAST FROM EL YUNQUE, SHOWING THE OUTLINE OF THE EAST COAST FROM CAPE SAN JUAN SOUTHWARD.

The greater part of the forested tract in the foreground belongs to the insular government
Note the smoke in the right center from a charcoal pit or conuco clearing, doubtless.

LUQUILLO NATIONAL FOREST.

gueros (not far from one-fourth the area of the island), as well as Vieques, Culebra, Mona, and the other outlying islands. It still occupies to a large extent the thin-soiled, rugged limestone hills, and has extended itself on the poorer soils of the north coast, principally at the expense of the dry tidal woodlands and moist deciduous forests of the limestone formation. In both situations, however, its composition is somewhat modified through the persistence of some of the more tenacious species of the formations displaced. On the deeper soils of the more gentle slopes and plains of the south coast country back from the streams the dry deciduous forest has in large measure been displaced by agriculture—nomadic agriculture originally, which burned and destroyed the forests and planted on their ashes. This land once cleared and then abandoned reverts to a forest growth with extreme difficulty, if at all. The open grass-covered savanna is the general result, with but here and there a tree where a particularly large individual escaped destruction or local conditions favored its getting a start and enabled it to compete with the turf. A transitional form of forest which might be called the "savanna forest" may occasionally be met with where the open savanna and the true forest join. Here the most hardy and drought-resisting varieties of trees form open stands in the grassy waste.

Although the dry deciduous forests vary from the closed chaparral form to that of the open savanna, they have certain well-defined characteristics. They are more or less leafless during the several months of the dry season and have a generally brown and parched appearance, evergreen trees such as the pajuil (86) being rare. Grass and other herbaceous growth under and between the trees is almost always present. Lianas are small and slender and absent entirely from the more open parts of the formation. *Tillandsia* (Spanish moss) festoons many of the trees and is the most conspicuous and most common among the epiphytes, here known collectively as piñuelas. There are a few other bromeliads and an occasional orchid. Exceedingly characteristic also of the formation are the pitajaya (120) and tuna (120), the tree cactuses and opuntias.

The trees themselves, rarely over 30 feet high, are short and thick-bodied, have a thick, fissured bark and a light, open, feathery crown which in the open is very apt to be flat-topped and umbrella-shaped, or to have its branches and foliage arranged in tiers. Leguminous trees with thorny branches and fine, usually firm-textured compound leaves, are particularly characteristic. Among the more common of these are guava (36), guama (37), tachuelo (54), cobana negra (44), algarrobo (45), campeche (50), moca (58), and many others. The wood of many of these trees is extremely heavy, hard, and durable.

Among nonleguminous trees are guayacan (60), jobo (87), almacigo (70), tea (64), guano (107), ucar (126), quebra hacha (94), and a host of others. The ceiba (105) is a conspicuous tree of the open savanna.¹

OLD FIELD GROWTH.

The old field type is an incidental and temporary one, in many places in a formative state. It varies considerably from place to place, the designation having been selected for all situations where there is a manifest tendency of land formerly cultivated and now more or less covered with grass to revert to forest. This tendency is at present general except on some dry south coast situations. The palm-studded hills most strikingly display this effort of nature to restore the balance. Palms, through their ability to grow in dry situations, are to that extent admirably adapted to assume this pioneer rôle. Their poor reproductive capacity, with the possible exception of the palma de sierra, renders them less aggressive than they otherwise might be. Another conspicuous old field pioneer growth is the poma rosa (133). The "poma rosa" type is very conspicuously developed on the uplands between Cayey and Guayama and in the vicinity of Aibonito. Natural reforestation even by this apparently more aggressive tree is slow. This may be due in part to a practice of successive clearings rotating this volunteer wood growth with intermittent cropping to rice, beans, and the like. Cutting for charcoal and for other uses also undoubtedly interferes.

CULTURAL FORESTS.

A description of the forests of Porto Rico would be incomplete without mention of its cultural forests. They not only cover a considerable acreage and are uniformly developed and kept up, but they are the most conspicuous forest growth on the island taken as a whole.

COCONUT PALM GROVES.

The palma de coco (4), or simply coco, is of uncertain origin,² but, however that may be, it has by one means or another been distributed

¹ One especially notable tree of this species near Ponce measures, according to Cook and Collins, 36 meters (118 feet) in circumference 4 feet from the ground, following the sinuosities of the trunk. Herrera says of the ceiba that it "has so great a shade that a strong man can not throw a stone across it. The tree is so big that a carpenter whose name was Pantaleo made a chapel of one hollowed out, being so thick that 15 men holding hand in hand can not grasp it."

² Cook ("The Origin and Distribution of the Coconut Palm," by O. F. Cook, Contributions from the National Herbarium, Vol. VII, No. 2) scouts the currently accepted opinion that this species originated in the Indian Archipelago and concludes: "The original habitat of the coco palm is to be sought in South America, the home of all the other species of cocos and of most of the closely related genera." He likewise controverts the common notion that the coconut originated as a strand plant, that the thick husk is an adaptation to enable the dispersal of seed by ocean currents, and that even the seeds thus transported have the ability to germinate and maintain themselves in competition with the other strand vegetation. "The coco palm," he says, "is unable to maintain an existence when subjected to the competition of the wild vegetation of tropical shores and forests." And, finally, "the idea (that they can not thrive in undisturbed nature) is recognized in the Cingalese proverb, 'The coconut will not grow out of the sound of the sea or of human voices,' and in the belief held among the same people that the trees will not thrive unless 'you walk and talk amongst them.'"

widely throughout the maritime regions of the Tropics. How long it has been cultivated can only be surmised, but sufficiently long at any rate for the development of many varieties. These varietal forms are mostly found in the islands of the Indian Ocean and the Malay region, little attention having been given to improvement by selection in tropical America.

These groves line the shore in many places and, when well cared for, are a profitable source of income. As yet the nut is the only product exported from the island.¹ There were, according to the 1912 tax assessment list, 6,556 acres of land under coconuts, having a total value of \$663,710, and an average value per acre of \$101.24 (maximum \$269.45 in Anasco and minimum \$24 in Comerio).

THE COFFEE FORESTS.

Coffee will grow without difficulty at sea level, but it thrives best in the upland district above 2,000 feet elevation. Because of this adaptability to soil and climatic conditions more or less unfavorable to crops requiring clean cultivation, its extension throughout the uplands of the interior was readily accomplished. Whether or not the coffee bush was ever cultivated in the open here, as in Brazil, it is now considered necessary to grow it under shade.² While areas of virgin forest were available these were used for coffee culture, the overwood being thinned and the underwood cleaned out and replaced by the coffee tree. In the absence of a natural forest growth the leguminous trees guava (36) and guama (37), and to a less extent bucare (59), are planted instead. The shade trees and coffee bush are planted at the same time, the former by their naturally rapid growth reaching a size to afford the requisite protection by the time the coffee tree comes into bearing.

The coffee forests are of interest from the forestry standpoint chiefly because of the protection which they afford to the steep mountain slopes, although, on account of the relatively thin cover and the small amount of cultivation they get, a certain amount of soil erosion necessarily occurs.

CACAO PLANTATIONS.

Practically no cacao is now cultivated commercially, although formerly it was to a limited extent. It is a semiforest crop growing

¹ The coconut yields in addition "coir," a fiber obtained from the husks and used in the manufacture of cordage and for many other purposes; "copra," the dried meat of the nut, which when pressed yields coconut oil and a "cake"; besides the various uses of the wood. (See Appendix 1, under "Coco.")

² The advantages which may be attributable to the shading of the coffee, particularly when leguminous trees are used for this purpose, are as follows: The trees hold the soil in place, at the same time protecting the superficial roots of the coffee tree, require little care or replanting, discourage by their shade the growth of weeds, diminish the cost of cultivation, and lessen the bad effects of drought, act beneficially in breaking the force of the strong trade winds and of the pelting of the torrential rain, and enrich the soil. The actual shade itself, however, is said to be unnecessary and even prejudicial. The use of leguminous shade trees is said to be a remnant of a prehistoric agricultural practice employed in the cultivation of both cacao (chocolate) and coca (cocaine) by the natives of Central and South America before the advent of Europeans and is still in favor among them.

under a forest-tree shade, like coffee, but, unlike coffee, it does best in the low country at elevations below 500 feet. It is chiefly of interest here as offering a suitable means of restoring a forest cover and providing an agricultural crop on some of the less fertile cane lands,¹ where a forest cover is particularly desirable because of its influence on bird life so necessary to the control of insect pests.

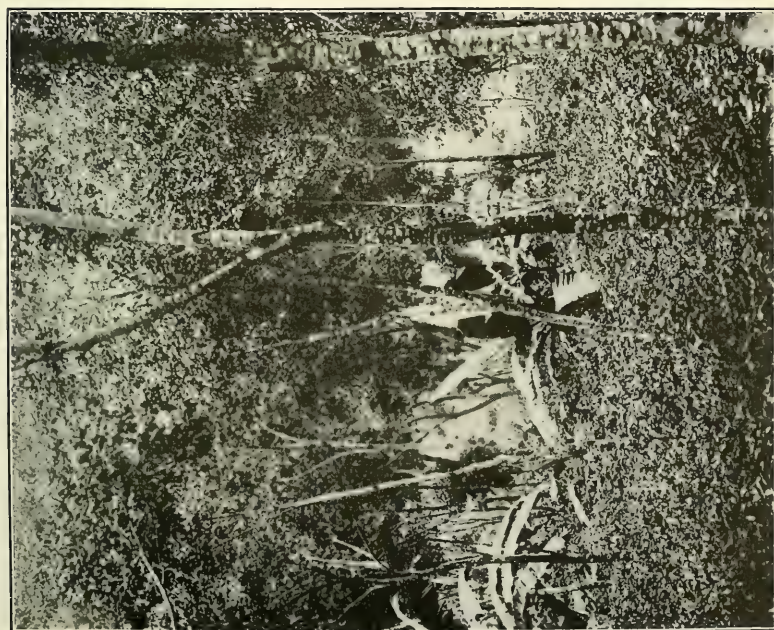
FOREST INFLUENCES.²

Forests make their presence felt through their influence on climate, on stream flow, and on soil erosion. In a country as abundantly watered as is Porto Rico whether the forests cause slightly more rain in the aggregate matters little. Within the forests, particularly those in the mountainous interior, the temperature of the air is appreciably milder and the humidity relatively higher than in the open. One effect of this may be observed in the formation during the dry season of clouds above the forests of El Yunque and vicinity, when none exist elsewhere. These rapidly disappear as they pass on to the westward and come in contact with the columns of heated air rising from the open slopes and cultivated valleys toward Juncos and Caguas. The modifying influence is likewise manifested in the cool air which descends after sundown into the open cultivated valleys from the wooded slopes of the coffee district.

The most important influence of the forests is in the checking of floods and erosion, though the conditions in Porto Rico are such as to make control of floods by forestation alone impossible. Throughout a greater part of the year the forest soils, except those of the limestone hills, are nearly, if not quite, saturated with moisture. Steep slopes and rain in the form of brief but torrential downpours are the rule and complete a combination favorable to most rapid run-off. These make it necessary to supplement forestation by a

¹ Cacao undoubtedly could be grown as profitably in Porto Rico as in Granada (British West Indies), where conditions of configuration, rainfall, soil, trade winds, etc., are very similar and where an even greater density of population prevails. According to a "Report on the Economic Resources of the West Indies" (by Daniel Morris, assistant director Royal Gardens Kew, in Kew Bulletin of Miscellaneous Information, Additional Series 1, 1898) cacao was first planted in Granada on mountain lands as it formerly was in Porto Rico, the lowlands being entirely in sugar estates. But later it was tried on the lowlands and found to rival sugar in productiveness. In 1895 Granada was said to be the only West Indian colony of Great Britain that was independent of sugar. An especial feature of the cultivation of cacao is that it can be raised to advantage on small holdings.

² Of more than passing interest in this connection are the following observations by Col. Flinter (see Bibliography), written in 1834: "The government has most wisely ordered that three trees should be planted for every one cut down. It is to be hoped that this order may be rigorously enforced; for, in the first place, wood is the great and principal agent in the atmosphere for the attraction of the clouds, * * * If these laws on this head are carried into force by the local magistrates the island will always have on it an inexhaustible source of timber; but if, on the contrary, these useful precepts are not followed, water will become scarce; the rivers will dry up; the fields will become scorched savannas for want of moisture; the cattle will find neither food nor shade from the noonday sun; and this beautiful and fertile island will at once be deprived of its enchanting verdure, its fertility, and its riches. This is not the dream of imagination or the ridiculous prognostication of ideal ills. I am aware that this can not happen before the expiration of a century; but it is the duty of governments and individuals to look forward to posterity. It is their duty, by wise and prudent measures, to foresee and prevent at the present day the ills which may be inflicted on future generations by undue considerations or concessions of temporary interests." (Italicizing is the author's.)



F-19770A

FIG. 1.—A COFFEE FOREST.

Probably the most conspicuous forest growth on the island. Photograph shows the two-story arrangement of the forest, being on a level with the top of the coffee bush.



F-62741

FIG. 2.—A COCONUT GROVE.

The most conspicuous tree growth along the coast.

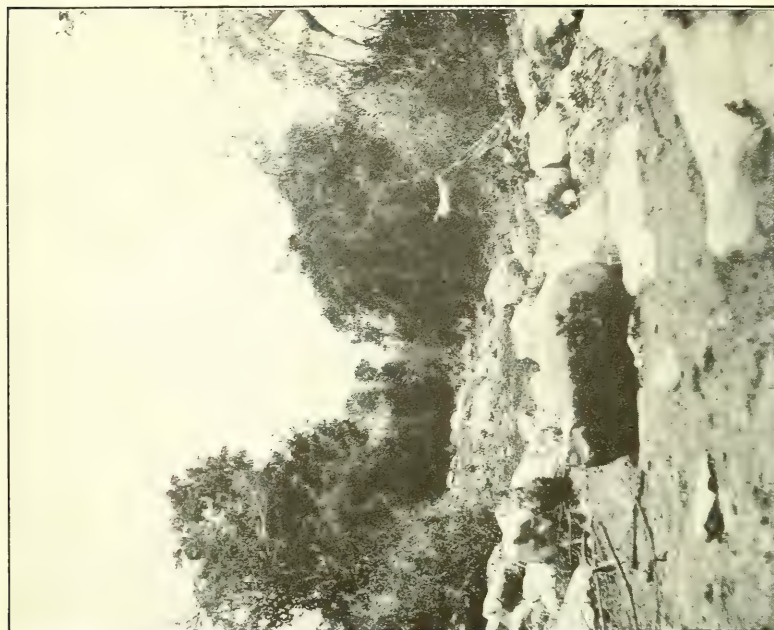
CULTURAL FORESTS.



F-52761

FIG. 1.—CHARCOAL KILN IN OPERATION.

When these operations are extended to the steep mountain slopes the way is opened for a rapid run-off of the rain falling on such slopes and floods in the lower stream courses.



F-52765

FIG. 2.—STREAM COURSE FLOODED IN TIMES OF RAIN; DRY AND BOWLDER STREWN AT OTHER TIMES.

The banks are eroded away and fertile fields encroached upon are the indirect results of charcoaling and conuco farming on the steep mountain slopes.

EROSION: CAUSE AND EFFECT.

succession of reservoirs and a cleaning up of the channels if any noticeable reduction of the eroding effects of floods is to be had.

Forests aid in conserving the water in the soil. The trees both aid the water in getting into the soil and then help the soil to hold on to it. In the first place, the trees break the beating force of the rain, which in the Tropics is considerable, and thus help to keep the surface layers of the forest soil from being beaten down and rendered compact and impervious like the soil in the open. Then the roots of the trees make the soil more open and accessible to percolating water. The roots and such ground cover and litter as there are impede the progress of surface run-off and afford the soil more time to absorb the water. With more water getting into the forest soil than in grassland soil, both being of a retentive character, there will be more water to find its way to springs and be gradually poured out into the rivers to sustain them during the periods of little rain.

The forest influences erosion in two ways: By reducing the force and interrupting the passage of the surface run-off in the catchment areas around the headwaters of the streams it slows up the washing away of the surface layers of the soil and greatly impedes gullying. At the same time the ability of the run-off to transport eroded material is very considerably lessened. A grass cover, if it forms a firm, well-knit sod, is also quite effective in resisting the erosive action of surface run-off. When, however, the grass grows in bunches and is interspersed with patches of bare ground or with tender, succulent herbage that dies out in dry weather, leaving the soil exposed, erosion and run-off is little affected. This is often the condition on the upper and drier slopes on the south side of the island. That these open slopes are not scored more deeply than they are is undoubtedly due in large measure to the tenacity of the soil.

It is when the run-off is gathered into the streams of the island and reaches the foothills country, where the character of the soil changes from the heavy clays of the interior to the lighter and more readily eroded coast soils, that the greatest damage is done. The rivers are generally too short to choke up and overflow, as would otherwise more frequently happen. Yet they are continually widening and shifting their channels, cutting off islands from adjoining fields, and undermining their banks. Frequently it is not so much the water that creates the havoc as the material which it picks up and transports. Besides the finer soil particles and gravel, large boulders are dislodged and rolled along with great destructive force. Thus the volume of water which comes from the hills may in the course of its passage to the sea be doubled by the material transported by it or dumped into it from caving banks.

A fringe of forest growth along the banks will materially lessen the liability to this kind of erosion. Certain of the bamboos are par-

ticularly suitable for this purpose and formerly were plentiful along the water courses in Porto Rico. But since sugar cane has become the all-important crop in the lowlands, the bamboo has been sacrificed to secure a few more feet of land or because it shaded the cane planted near the edge of the field. The folly of this procedure can be seen in places where the extra feet of cane rows thus secured at the sacrifice of bamboo and several more with them have been subsequently undermined by flood and dumped into the river.¹

The close relation of forests to stream flow and erosion is not difficult to observe in Porto Rico. Compare, for instance, the lower reaches of the north coast rivers, particularly those rising in the coffee district or the Luquillo, with the south coast rivers, as, for instance, the Portugues. The former have relatively few abandoned channel beds and less spreading stream bottoms, are obstructed only by sandy or gravelly bars and relatively small boulders, and show a reasonable flow of water even in the dry months. The Portugues and other south-side rivers, which are largely fed by the rains falling on the steep grass slopes of the Cordillera Central, have wide, dry bottoms showing often no less than six different channels separated by low islands, and many shoals, remnants of a former river bank. The boulders, which are everywhere strewn about, are several times the size of those in the north coast rivers, the banks are often steep and undermined, and the stream is of almost inconceivable insignificance on the midst of surroundings indicative of such destructive power. The many streams and waterfalls in the heart of the interior flow from the wooded slopes (even when swollen by heavy rains) practically clear, carrying but little sediment; on the other hand, the waters of the south coast embayments at the mouths of the rivers are red-brown in the flood season with the soil brought down by the rushing torrents.

Many examples might be found in the Tropics of serious injury resulting from destruction of the forest or of benefits following its restoration. Owing to reforestations effected on a large scale, the rainfall on the island of St. Helena has actually been doubled since the time of Napoleon I; and in Lower Egypt, where in the eighteenth century rain only fell on from 10 to 12 days in the year, the number of rainy days nowadays reaches from 30 to 40. On the other hand, in Syria and Palestine there are numerous regions which were formerly in a flourishing condition but have become arid and waste in consequence of the destruction of forests.² In the West Indies themselves, the experiences of Martinique are particularly instructive. Here as early as 1843 the man-

¹ The following, which bears closely on this situation, is quoted from the 1907 report of Lorrin A. Thurston, chairman of the committee on forestry of the Hawaiian Sugar Planters' Association:

"In the past the subject of forestry has been largely treated by this association as an interesting incident, but not as one of direct concern or of possible immediate benefit or profit to its members. *Within two years I have heard of trees bounding fields being cut out because the shade injured the adjoining cane.*

"In all earnestness I urge upon the association that the time for this view of forestry and its possibilities in Hawaii has passed, and that the preservation, propagation, and utilizing of forests and forest products should from this time forth be made one of the leading features of the efforts of the planters' association, both by it as an organization and through the individuals and corporations which give it its strength." (Italicizing is the author's.)

² General report by C. Capolletti, of the proceedings of the Navigation Congress at Milan in 1905.

ufacture of charcoal was recognized as the most serious single cause of the forest destruction which resulted in timber shortage, interruption and impairment of stream flow, soil wastage, damage to valuable agricultural lands through erosion, and shortage in the supply of water for power and other purposes. To remedy this situation the exportation of charcoal was prohibited, and stringent measures were adopted to regulate its manufacture, sale, and distribution. Most important of all, however, a forestry association¹ was formed which is supported by the Government. It has not only made a beginning in experimental reforestation, but is working through the schools, the celebration of Arbor Day, and the distribution of forest-planting stock at cost to arouse public interest in forestry.

The subject of conserving the forests for their influence on the water supply has not been without consideration in Porto Rico, since there appears in the "law of waters" this very significant language: "The colonial secretary shall also direct that a study be made of the portions of the basins and watersheds which it is advisable to keep wooded in the interest of a control of the water supply."² Like many another good piece of Spanish legislation, it remained legislation to the end. It is still, however, a part of the laws of the realm to-day and awaits as formerly official action. So much and more should be undertaken without delay.

COMMERCIAL ASPECTS.

In the larger commercial sense the forests of Porto Rico are insignificant. Leaving out of consideration coconuts and coffee, there is not a single article of export which is in any sense a forest product. The forests are, however, of tremendous importance as a source of domestic wood supply.

LOCAL TIMBER AND WOOD SUPPLY.

The estimated present resources of those forest lands capable of yielding saw logs are placed at 96,442,500 cubic feet (1,155,000 cords). Of this amount, however, there are only 4,592,500 cubic feet (27,500,000 feet, or 55,000 cords) of saw-log size, the great bulk being chiefly suitable for fuel, small house logs, and piling, posts, and the like. There are about 110,000 acres of such lands on which it is believed the average yield will not exceed 876.7 cubic feet (10.5 cords) per acre, of which 41.7 cubic feet (0.5 cord) will be found suitable for saw logs. On another 333,000 acres, comprising small wood and brush lands, including mangrove, the produce consists largely of fuel, house piling, and other small materials, averaging scarcely 334 cubic feet (4 cords) per acre. This will add another 111,222,000 cubic feet (1,332,000 cords) to the general resources. The total present supply is, therefore, 207,664,500 cubic feet (2,487,000 cords).

¹ "La Societe Martiniquaise des Amios des Arbres" was founded in November, 1909.

² Art. 59 of the Spanish law of June 13, 1879, which was extended over Porto Rico by Royal decree of Feb. 5, 1886, and reenacted and amended by the Legislative Assembly of Porto Rico, Mar. 12, 1903.

Stated in one lump sum it seems considerable, yet it is equivalent to scarcely 185 cubic feet per capita—less than the annual per capita consumption of the United States or Canada.

The value of this resource is \$6,780,000, on the basis of 3 cents a cubic foot for all material except timber, which is estimated at 15 cents. The value of any by-products and the far more important soil protective value are, of course, left entirely out of account. The wood value alone, however, if invested at 5 per cent, would yield in interest approximately \$340,000. The expenditure through an appropriation from the insular treasury of less than 6 per cent of this latter amount, or about \$20,000, for a forest service to protect and improve the principal, would seem, therefore, to be a fully warranted, sound, and businesslike policy.

LUMBER AND TIMBER IMPORTS.

Commercial expansion during the last few years has created a heavy demand for building lumber, timbers, and the like, which, because of the scarcity of suitable native woods, have been imported. Naturally most of this material has come from the United States, the Gulf ports more particularly.

Imports of forest products from the United States for the fiscal year 1911 totaled \$1,308,579, an increase of 225 per cent over those of 1909. Besides this the United States supplied furniture and other manufactures of wood amounting to \$684,560. Foreign lumber, timber, and manufactures to the amount of \$131,623 were imported, of which material worth \$14,616 came through the United States. The gross value from all sources was thus \$2,124,762, of which lumber, timber, etc., exclusive of naval stores or manufactures of wood, amounted to \$1,382,506.

The quantity of wood imported, exclusive of such products as shingles, box shooks, etc., amounts to 9,120,872 cubic feet (54,616,000 feet b. m.), including 8,382,064 cubic feet (50,192,000 feet b. m.) in lumber, scantling, and sawed timber from the United States, and 738,808 cubic feet (4,424,000 feet b. m.) from abroad. In addition, there was imported from the United States 26,717 cubic feet in hewed timber. Thus the grand total of wood imports amounted to 9,147,589 cubic feet, or about 8.2 cubic feet per capita.

DEMANDS FOR WOOD.

The demands for wood products are about half for commercial and half for domestic uses. Most of the commercial demands are supplied by imports. The commercial demands supplied by native-grown wood come chiefly from power development, which takes 3,633,336 cubic feet (43,513 cords) each year, equivalent to 3.25

cubic feet per capita.¹ The raw materials for the manufacture of furniture and novelties, native carts, ox yokes, and the like, also railroad ties, for narrow-gauge roads principally, posts and heavy structural timbers, in the aggregate probably amount to less than 1 cubic foot per capita.

Probably not less than 11,180,000 cubic feet (133,892 cords), equivalent to 10 cubic feet per capita, is consumed for domestic purposes. This means that an average family of five persons consumes only a little more than half a cord of wood each year. The demand for house piling, rafters, flooring, and the like is at the present time inconsiderable—not more than 2 cubic feet per capita (2,236,000 cubic feet)—because of the great scarcity of wood over most of the island and the prevailing low standard of living, especially among the rural population.

The various present demands for wood, aside from the manufactures of wood, may thus be summarized:

Character of demand.	Source of supply and uses.	Per capita.	Total.
		<i>Cubic feet.</i>	<i>Cubic feet.</i>
Commercial.....	Imports, building material, etc.....	8.2	9,147,589
	Local, fuel only.....	3.25	3,633,336
Domestic.....	Local, fuel.....	10.00	11,180,000
	House pilings, and poles, posts, etc.....	2.00	2,236,000
	Total.....	23.45	26,196,925
	Net total, excluding imports.....	15.25	17,049,336

NOTE.—The domestic demand is entirely an estimate; the commercial demand is based on the census and customs reports for 1910 and 1911, respectively.

The present status of the supply and demand is graphically represented in figure 7, which shows that the present per capita supply, at the rate it is now being consumed, will be exhausted in about 12 years. Yet at the present rate of production it will require more than 45 years to produce a similar supply, or nearly four times as

¹ Manufactures, Porto Rico; Bulletin of the Thirteenth Census, 1910: "Closely related to the question of kind of power employed is that of the fuel used in generating this power. * * * Porto Rico has no mineral fuel, and its wood supply is being depleted as manufactures increase. The following table shows the quantity of each kind of fuel used in 1909."

Industry.	Anthracite coal.	Bituminous coal.	Coke.	Wood.	Oil, including gasoline.	Others.
	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Cords.</i>	<i>Barrels.</i>	<i>Tons.</i>
All industries.....	946	41,988	368	43,513	1,036	520
Bread and other bakery products.....	5		6	13,444	75	
Coffee, cleaning and polishing.....	128	1,293	234	2,846	33	
Liquors, distilled.....	200	2,712		737		
Sugar and molasses.....		31,808		19,656	365	275
Tobacco manufactures.....		790			17	
All other industries.....	613	5,385	128	6,830	546	245

long to produce as to consume it. New growth, however, during the period will extend the supply to slightly more than 16 years. It is, however, not to be expected that the island will be denuded of all woods at the end of this period. Experience teaches us that what actually happens in such cases is that consumption decreases as more

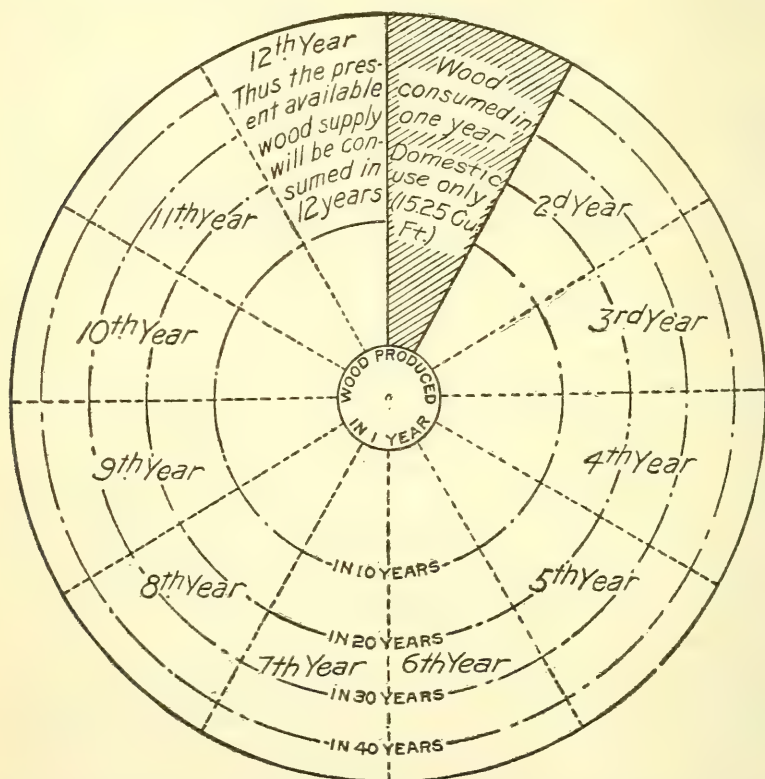


FIG. 7.—Per capita supply, production, and consumption of wood in Porto Rico, showing the rate at which present merchantable wood supply is being drawn on each year to meet domestic need, and the rate of its replenishment through new growth. The large circle represents the present per capita wood supply (185 cubic feet) exclusive of imports. The small circle represents per capita of wood production in one year (4 cubic feet), and the dot and dash circles the corresponding production per decade. (Based on a present annual growth of 10 cubic feet per acre per annum, equivalent to 4 cubic feet per capita.)

and more people are unable to pay the advancing prices. In the present instance it simply means a progressively increasing privation.

TREND OF FUTURE DEMANDS.

Education and the establishment of a more permanent form of agriculture will inevitably raise the standard of living among the lower classes and increase correspondingly the demands on the forests for both building materials and fuel, and besides these is the normally increasing demand occasioned by increased population. Kerosene and denatured alcohol can not, at least for a long time,

take the place of wood. The change would necessitate not only the displacing of the customs of centuries, but an investment in stoves and burners, which the average person can not afford. The domestic per capita consumption of fuel can therefore be expected to rise from year to year.

The sugar mills are now the largest commercial users of native wood. Under present improved methods the refuse cane fiber, known as "bagasse," is burned under the boilers, which effects a considerable wood saving. Some wood is still required to sustain this "bagasse" fuel, but as one "central" has already substituted crude oil for this purpose with satisfactory results, it is possible that in time all the larger mills at least may likewise adopt that fuel. It is thus probable that the maximum demands on the native wood supply have been reached by this industry. A gradual decline may consequently be expected.

The bakeries are the second largest commercial consumers of wood, and they demand cordwood of regulation size. The possibility of their changing to oil or other substitute fuel seems remote at the present time. The business is conducted on a small scale, with too limited a capital to justify such an outlay. The Army bakeries also consume a relatively large amount of cordwood. Any immediate decrease in demands of these or other industries where wood is largely used in the generation of power is thus hardly to be looked for.

BALANCING SUPPLY AND DEMAND.

Everything points to a sustained or an increased demand for wood. Commercial expansion can and will be taken care of by an increased volume of imports. But local and domestic needs accommodate themselves less readily and less promptly to new sources of supply. With production falling behind consumption, hardship and deprivation must be the inevitable consequences. This condition promises to grow more serious unless relief can be had through increased production. Two ways are open to effect this—planting new forests and improving the existing woodlands.

The restoration of a reasonable balance between cleared lands and forests is necessary. One-half million acres under prime forest growth will scarcely more than meet the situation. At present a large part of the 443,000 acres of timber and brush land yields not more than 10 cubic feet per acre a year, worth, at 3 cents per cubic foot, about \$135,000. The improvement of these and the planting to new forest growth of 100,000 acres besides would provide approximately one-half acre of productive forest per capita, which is about the minimum required by a people to meet their own needs. A conservative estimate of the average annual growth to be expected on such area under forest management would be 30 cubic feet per acre,

worth in the aggregate approximately \$490,000. Accordingly, to neglect to adopt a constructive forest policy for the future will mean the loss of a possible income from wood products of \$355,000 per annum.

FOREST INDUSTRIES.

CHARCOALING.

One could hardly expect that with depleted forests there would be many or very flourishing industries.¹ The charcoal industry is probably the leading forest industry of Porto Rico, as of many other of the West Indies. Charcoal is the fuel most generally used, particularly for domestic purposes. It is the only fuel of the poorer classes in the cities and is still in use to a great extent among the better classes also. Generally speaking, the charcoal is of exceedingly poor quality and small size. Some is scarcely larger than pea coal. Such stuff, the good and the bad indiscriminately, sells in San Juan for as high as 25 cents a can.² A sack holding about 2 bushels sells for from \$1 to \$1.25.³

The manufacturing part of the industry is carried on in a crude and haphazard way. All sizes of material, even to brushwood and small limbs scarcely one-half inch thick, and all kinds of wood are fired in the same heap. Because of its crookedness the wood is cut into short lengths—4 to 6 inches. The kilns are of poor and crude construction, and the fire control consequently is ineffective. Too rapid combustion is thus apt to occur and great waste results through the complete consumption of part of the wood, or incomplete combustion may leave some of the wood only partially carbonized, which renders the product very variable in burning and heating qualities.

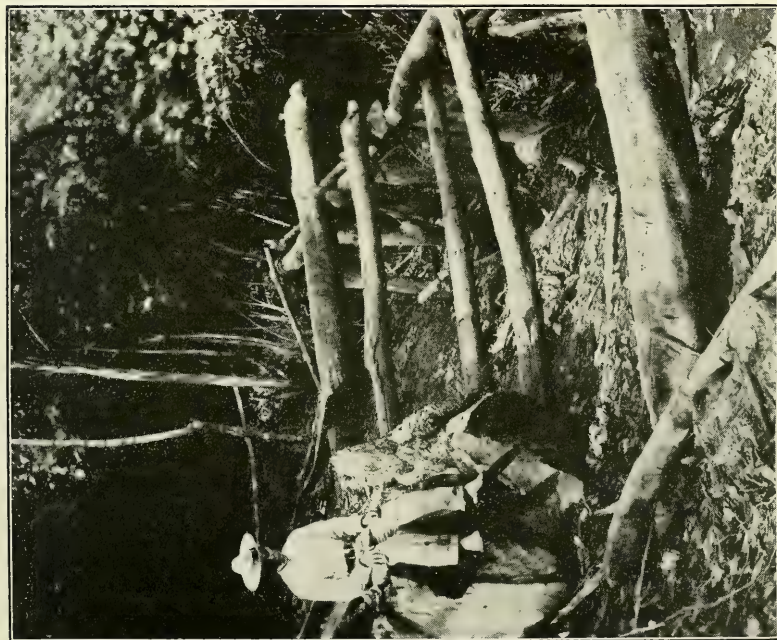
The sources of supply are numerous. Most of the material comes from the clearing of land for agricultural use, but the mangrove swamps and the south coast hills furnish considerable. In some instances the charcoaling is done by contract with the bona-fide owners of the land, especially of land being cleared for the cultivation of sugar cane. In this case the large material is frequently cut and sold at from \$1.50 to \$2 a ton⁴ to the "central." The charcoal opera-

¹ The census (1910) reports 8 establishments classed as "lumber and timber products" industries, having a total personnel of 171—26 proprietors, 22 clerks, and 123 laborers. These industries represent a combined capital of \$113,392 and handle a product valued at \$268,719, of which \$90,301 is the value added by manufacture.

² Since the advent of the automobile the 5-gallon gasoline containers have become very plentiful and have been adapted to a variety of uses, one of which is as a unit of measure for the retailing of charcoal.

³ A small amount of charcoal is brought in from Santo Domingo, but only one instance is known to the writer of any being brought from the mainland. The sale of this, however, under adverse market conditions yielded a slight profit and shows not only the high price of the native product but the possibility of developing a successful and profitable competition with it.

⁴ The wood is thrown loosely into the car and is of varying lengths and frequently crooked. Under these conditions a car having a capacity of 1,000 cubic feet weighed 22,548 pounds, or about 22½ pounds per cubic foot. Making an allowance for the condition of the wood in the car, 150 cubic feet seems a fair equivalent of a properly cut and stacked cord. On this basis a cord would weigh about 3,400 pounds.



F-54250

FIG. 1.—SAW-PIT IN THE HEART OF THE FOREST.

Trees often cut in such inaccessible places that the logs have to be squared and cut into plank where they are felled and carried out by hand or skidded a plank at a time.



F-57978

FIG. 2.—SKIDDING OUT PLANK SAWED IN THE FOREST.

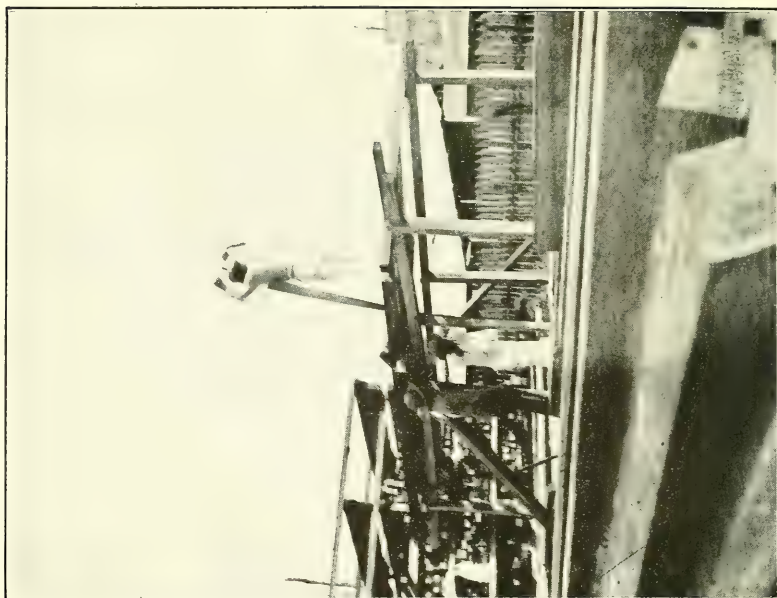
Note the method of yoking the oxen. Skidding is done with these animals in what would seem impossibly steep places.

LUMBERING.



F-2713

FIG. 1.—CLAPBOARD MAKING: FROM THE HARD OUTER
PORTION OF THE ROYAL PALM.



F-3786

FIG. 2.—NATIVE SAWMILL AND LUMBER YARD.

FOREST INDUSTRIES.

tor may be given the material for clearing up the land or he may pay the owner a stipulated amount per sack of charcoal yielded.

Often the charcoaling is not even done "by your leave," since it is an adjunct to "conuco" farming. When the squatter finds a piece of woodland which he wants to cultivate he may first cut such material as is suitable and make charcoal from it, or a charcoal burner may cut over a piece of land for charcoal without having an intention of subsequent cultivation. The public lands have by this process been largely despoiled of their forest growth.

LUMBERING.

As an organized business lumbering hardly exists at all. Probably the nearest approach to it is in the Sierra de Luquillo, where a few lumbermen or woodcutters are to be found. They own their own implements and log on contract; that is to say, if any one wants a piece of ausubo for an ox yoke or bull cart or any other special material these men will go in and get it out for him. Their method of lumbering is a very gradual process of culling. Having found a suitable tree, they fell it and cut it into logs of the desired length. The log is squared with an adz, then a knob is fashioned at one end, to which a rope may later be made fast to drag it out by. Finally the log is placed on a rudely constructed scaffolding of poles erected on a hillside and sawed by the world-old pit-saw method. If they may be skidded directly from the pit, the planks are not sawed through the whole length of the log, but the log is left intact for a short distance back from the knob end to facilitate handling. Otherwise each plank is entirely severed from the log and carried out by hand to a place accessible to oxen. There the separate planks are assembled as they were in the log, a rope is made fast to the knob, and they are skidded the rest of the way to their destination or to where they can be loaded on a cart. The smaller logs and pole and post timbers are skidded singly or sometimes several at a time.

Skidding is accomplished by oxen on slopes where such work seems impossible. Grade appears to receive scant consideration, the skidding trails in places descending straight down the slope. Frequently these are hollowed out, whether intentionally or by the wearing of the logs is not evident, and stakes are driven at the side, where they turn sharply around a shoulder or follow obliquely down the hillside. After a time erosion supplements the wearing of the logs and the trails become so deep in places that they have to be abandoned.

WOOD-WORKING INDUSTRIES.

With this system of lumbering there is, of course, no need for sawmills.¹ What few mills there are—located principally in the

¹ Flinter (see Bibliography) reported one water sawmill on the island in 1830 near Camuy.

seaport cities, San Juan, Mayaguez, and Ponce—resaw American lumber. Some of these carry a small stock of native logs which they saw on order for special work.

One of the largest manufactories on the island, located near San Juan, is devoted to the making of cigar boxes. The stock, cedro (71), for this factory is entirely imported, in large measure if not wholly, from Cuba. It comes in strips already cut to the proper thickness, namely, $\frac{1}{4}$ inch and $\frac{3}{16}$ inch. The annual consumption amounts to about 2,000,000 superficial feet, or something less than 1,000,000 feet b. m. A box of the size to hold 50 cigars contains about $1\frac{1}{2}$ square feet of material.

The trunk and match industries use considerable wood, but it is all imported. Furniture and other cabinet work and novelties, of which very little is produced, are to a large extent the product of hand labor. Native woods are almost exclusively used. The furniture is very excellently made, and, though of a style somewhat different and considerably more ornate than our furniture, is very attractive and pleasing. It especially brings out the beauties of the native woods, which, though practically unknown to commerce, possess very desirable qualities of both grain and color. The native furniture trade is unfortunately doomed to extinction, because of its inability to meet the competition of cheap machine-made furniture from the mainland.

FOREST PRODUCTS.

The forests of Porto Rico yield a large variety of gums, resins, fibers, coloring and dyeing materials, edible fruits, and the like, having a decided commercial value if systematically developed. Some of these are well-known articles of commerce, as anatto, fustic, and other coloring and dyeing materials. Although none are produced in sufficient quantity for export, most of them are to be found on sale in the public markets. It is doubtful if the various products and their still more varied uses have ever been completely catalogued. Many of the more important uses are given in Appendix 1, where, however, the wood uses are the ones chiefly considered.

FOREST PROBLEMS.

Every acre of land best suited, either temporarily or for all time, to forest production should be devoted to that use. Every acre of land around the headwaters and along the banks of the rivers on which a forest cover would offer a protection superior to the present cover against erosion and soil wastage should be forested. All forested lands and those to be forested should be so managed as to yield a maximum of the products most needed by the local communities and industries. The forestry program should also provide suitable

protection to the birds, live stock, and even man himself in the form, respectively, of small groves at intervals throughout the cane and tobacco districts, open cover in the pastures, and shade trees along the roadsides. Of scarcely less importance than these phases of the practice of forestry are painstaking investigations and a thorough campaign of educational propaganda.

PLANTING.

The planting of new forests is by far the most important, in point of magnitude at least, of the forestry work to be done in Porto Rico. Tree planting figured rather conspicuously in the early Spanish laws. "Law First"¹ of "Laws of the Indies," which concerned the allotment of lands to settlers, provided "two 'huebras' of land for orchard, and eight for planting other trees," while "Law Eleventh" promulgated by Emperor Charles in 1536, provided even more explicitly for the planting of "willows and trees," so that in addition to other purposes "it be possible to use the timber (wood) which might be necessary." As the Indies were generally well wooded, these laws, it may reasonably be inferred, were merely Spanish laws devised to meet conditions in Spain and more or less perfunctorily extended over the new possessions. Certain it is that they were never given force or effect in Porto Rico.

The need for reforesting the headwaters of the streams has already been mentioned. In most cases, however, protection can be as well supplied by the forests managed from the standpoint of wood production. It will not often be necessary to refrain from any cutting whatever. A system of harvesting the wood crop which will expose the soil on the steep slopes as little as possible to the unbroken force of the sun, wind, and rain, will usually be sufficient. For planting work along the streams to prevent the banks from washing, it may be necessary to adopt special material, such as bamboo. But with proper care even this could be harvested without impairing its usefulness as a soil binder.

In planting for the production of a wood crop the first consideration is, what products are most needed. Many would plant mahogany, ebony, rosewood, and all the other valuable cabinet and dye woods solely because they are valuable. Some time in the future it may be good forestry to try producing these woods for export, but that time will not come until the virgin supply of Santo Domingo and other countries is much nearer exhaustion and the growth qualities of these woods is much better known than now. In the meantime the home market is urgently in need of attention; its requirements are known, and it can be profitably supplied. Those trees which will produce fuel wood in the greatest abundance, the shortest time, and the most

¹ See p. 9.

suitable quality should unquestionably be the ones most extensively planted. What the species are that will best fulfill those requirements is now unknown and must be determined by experiment and investigation.¹ The discovery of the best varieties of woods for the manufacture of charcoal is also of the utmost importance.

Second only to the need for fuel is that for an increased supply of suitable woods for various native uses. At present the demand is more or less irregular and specialized. Particular kinds of wood have particular uses and there is practically no demand for wood for native house construction except for underpinning, sills, and the like. The advancement of civilization on the island will necessitate the improvement of housing conditions in the interest of public health, sanitation, and morality; and universal education through the public schools will inevitably set up a standard and a demand which will not tolerate present conditions. To meet this demand the properties of the various woods will have to be closely studied and very likely the introduction of some such species as the pine will be found desirable.

There is at least one native industry of large proportions that might possibly produce its own box material through the practice of forestry—the cigar industry. At present the cedro used by the Porto Rican trade comes almost exclusively from the virgin forests of Cuba. This wood is particularly prized for its lightness, clearness of grain, and strong yet pleasant aromatic odor. It is, of course, largely conjectural how far these properties would inhere in the wood of a planted growth. The cedro (71) is a rapid grower under favorable conditions of soil and climate.

Undoubtedly many trees could be planted which would yield products of bark, leaf, or sap for use as the basis of new industries.² The achiote might be set out on a steep hillside, several acres of it together. The gathering of the seed coats and the extraction of their coloring matter would furnish light labor for a number of persons at certain seasons of the year, if not the year round. Then there is the

¹ One such species undoubtedly is the *Acacia palida* (41), stands of which, according to investigations of the Philippine Bureau of Forestry, will yield over 13 cords per acre in 2 to 3 years. It is splendidly adapted for the reforestation of grasslands wastes either as a permanent crop or as a pioneer and nurse crop for subsequent plantations of more valuable but less hardy and aggressive species. It may also be planted to advantage on worn-out agricultural lands and, after one crop of firewood is harvested, the twigs and tops plowed into the soil as a green manure. (The author is indebted to Mr. H. M. Curran, formerly of the Philippine Bureau of Forestry, for calling his attention to the work done by that bureau and its published report concerning this tree, entitled "Ipil-Ipil—A Firewood and Reforestation Crop," by D. A. Matthews, Bulletin No. 13, Philippine Bureau of Forestry.)

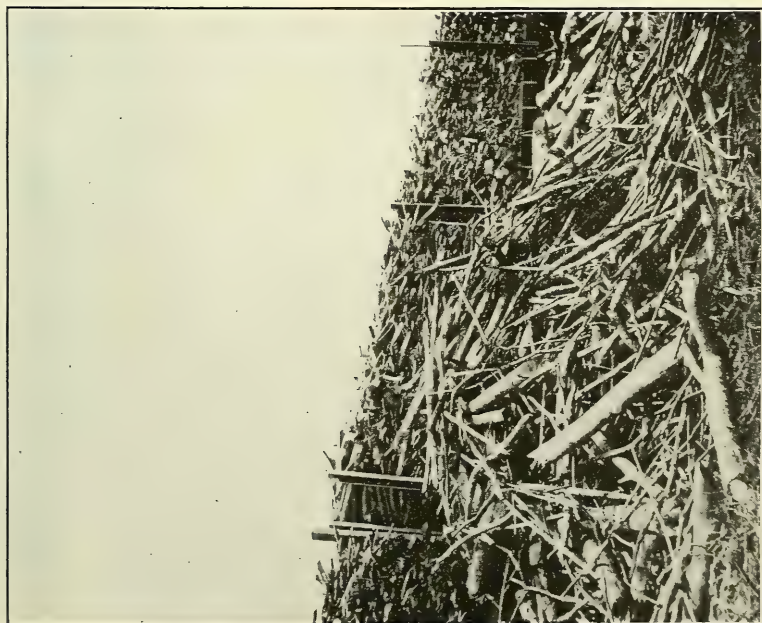
² Dr. Seaman A. Knapp, in his "Report on Investigations of the Agricultural Resources and Capabilities of Porto Rico" (Senate Doc. 171, 56th Cong., 2d sess.), emphasizes the need of new industries. He says: "The early establishment of a number of minor industries closely related to agriculture is of vital importance to future prosperity. The object of such industries is to give profitable employment to the wives and children of farm laborers, so that the earning ability of the home may be doubled, and in some cases quadrupled. * * * Many philanthropic Porto Ricans suggested that the farm laborers on the coffee and tobacco plantations scattered upon the mountains * * * could never derive the full advantage of free education * * * until they were gathered into small villages and became amenable to society."



F-52743

FIG. 2.—RAILROAD TIES.

Used largely on the narrow-gauge roads which bring the sugar cane from the field to the mill.

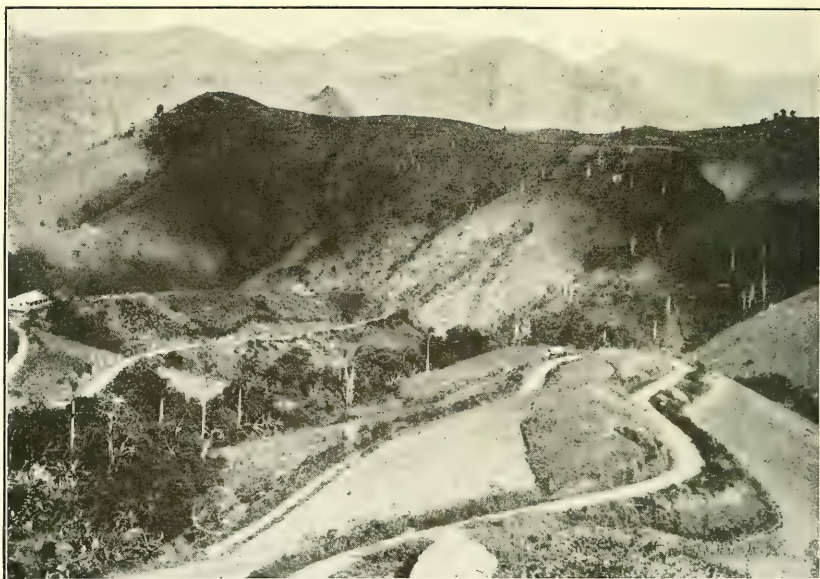


F-52716

FIG. 1.—CORDWOOD ON THE CAR FOR SHIPMENT TO THE SUGAR CENTRAL.

These factories use nearly 20,000 cords per annum for power and heating purposes. (See note at bottom of page 41.)

FOREST PRODUCTS.



F-19764A

FIG. 1.—A SECTION OF THE COMERIO-BARRANQUITAS ROAD, ENTIRELY DEVOID OF SHADE OF ANY KIND.



F-27954A

FIG. 2.—THE FAMOUS MILITARY ROAD.

This stretch of roadway just outside of Caguas is attractively shaded by overarching flamboyans.

IMPROVED ROADS.

emajagua, which might be planted as a soil protector and yet be so managed as to yield a regular amount of fiber and fagots each year. The poma rosa could be made to furnish a continuous supply of hoop material for baling tobacco, fruit boxes, and the like, as well as fagots. The growing and tapping of tabanuco for its resinous sap likewise has possibilities. These and many others, the bamboos especially, are worthy of careful study and consideration

While recognizing the larger and more purely economic aspects of tree planting, it will not do to neglect esthetic and utilitarian considerations. No country can afford to be ugly or to neglect the comfort, both physical and mental, of its own or a visiting people. The roads of the island, particularly those through the lowland country, are usually hot and unattractive for lack of proper shade. There are some notable exceptions to this, but their occurrence serves rather to heighten the discomfort after they are passed. Such a one is the avenue of flamboyant bordering the military road between Caguas and Cayey. The kind of tree is of nearly as much importance as the fact that there are trees at all. Thus the almacigo and jobo, to mention two of the most common, have little to recommend them for roadside planting, except their ease of propagation and rapidity of growth. In the open country, trees that are tall and carry their branches high on a straight, clean trunk offer little obstruction to the view or to the circulation of air, yet they protect the roadway during the midday hours from the beating sun, and relieve the monotony of cultivated fields and pastures.

There is much concern about the scarcity of bird life in the cane country and the consequent prevalence of destructive insects. An occasional grove of trees would help this situation by furnishing the birds a refuge and nesting place; yet what few patches of woodland there are are constantly being cleaned up to get a few more square feet in cane.¹

Systematic tree planting could be carried on in the pastures, even those which are actually utilized for grazing. There are several of the leguminous trees the pods of which are very nutritious and very

¹ In this connection the following from a letter of the U. S. Biological Survey to the Board of Commissioners of Agriculture published in its second annual report is of interest:

"In connection with the increase of island birds Mr. Wetmore suggests the great desirability of providing them with more shelter than they now have. The grackles and yellow-shouldered blackbirds, for instance—nest and roost in the palms. Can not the individual owners of plantations be sufficiently interested in the matter to plant royal palms along the roads leading through the cane fields? The island kingbirds appear to be very useful, and they need small perches from which to watch for insects. Bamboo planted along the streams and the drainage ditches would not only favor the three species mentioned above, but would also provide shelter from the sun for the green heron and the anis. For mocking birds, small brushy areas are essential, but these need not be of any great size, and if hilltops unfit for cane or other crops be left and not denuded of brush they will answer well the purpose.

"Mr. Wetmore further suggests that along the coast restrictions should be placed upon the total clearing of areas of mangroves by the charcoal burners, and special care should be taken not to disturb the rookeries of herons—the snowy, little blue, and little green species."

much sought after by stock. These trees, besides affording food and shade for the cattle and naturally enriching the soil and improving the grass crop, could be cut at intervals for fuel.

MANAGEMENT.

The problems in forest management are those first of all which concern the protection of the present forests, such as the regulation of "conuco" farming, charcoal burning, and wood trespass in general, which alone will undoubtedly yield ample returns. Yet these little more than open the way to the real problems. The need for the improvement and conservative management of the mangrove has already been referred to. The insular lands, too, and to a large extent the privately owned lands which still remain forested, should not only be kept so but should be improved under systematic management. The nature of such management will depend on a variety of circumstances. Its fundamental purpose, however, will be to favor the growth and reproduction of those trees best suited to the needs which the particular forest is intended to serve. If the most suitable species do not occur in the original growth, it will be necessary to introduce one or more of them by planting; but careful investigation will usually discover among even those commonly thought to be useless qualities of excellence undreamed of.

INVESTIGATION.

In a country like Porto Rico, where so little is known about the native trees, their habits and requirements, it would be folly to ignore the needs for scientific study and research. The forest crop grows and matures comparatively slowly, and it accordingly takes several years for a mistake to become fully manifest. It thus will not do to go ahead blindly and plant large areas with little-known species, to find later that they are not suitable. Provision for investigative work is therefore indispensable to the practice of forestry.

EDUCATION.

One can not expect those who all their lives have been engaged in wasting and destroying what has come to them without exertion to see unaided the advantages of turning about and putting exertion into its production. Educational work of a very thorough and earnest sort is necessary to induce a people to support a tree-planting or other forestry campaign because usually the benefits are either obscure and indirect or are obtainable only by a future generation.

There are many educational means by which forestry can be carried to the people. The public-school system is, of course, one of the first and most effective means to be considered. Then the more advanced thinkers may be formed into forestry associations for discussion and propaganda, and others may be reached through popular publications, lectures, and the press.

Already a considerable interest is manifested by different branches of the insular government in improving forest conditions. Several of the sugar companies are also interested in planting up waste lands and in the open planting of leguminous trees in their bull pastures to provide green forage, improve the grass crop, and furnish shade for the stock. They are also planting for ornament about their grounds, along the roads, and bordering the cane fields.

INSULAR FOREST POLICY.

It must be evident that a program which has for its fundamental purpose the improvement of conditions affecting both directly and indirectly the interests of a whole people can not be left to private initiative. It must be undertaken and directed by the insular government itself. An efficient and well-equipped insular forest administration¹ should, therefore, be provided, and a forest policy be established which would make effective the following work: A campaign of education, investigative work in forestry, the care and management of the most suitable parts of the insular domain as insular forests, and cooperation with private individuals, municipalities, and others interested in the practice of forestry. The practice of forestry and forest experimentation is a distinctly long-time operation. In scarcely less than 10 years are any practical results forthcoming, unless an experiment results in conclusive and disastrous failure. Only when fuel wood or other small-sized material is the object of production can any conclusive results be obtained even in 10 years. For larger products 30 or more years will ordinarily be required. The necessity for taking a long look in advance and the desirability of fixing by permanent legislation the organization and scope of the work are thus apparent, stability, permanence, and continuity being indispensable conditions.

In weighing the advisability of taking such a step, the conditions and tendencies of the world supply of forest products can not be overlooked. The time is not far distant when the countries which produce the great bulk of the world's supply of the common economic woods will cease to have any considerable amount of timber to export. In anticipation of these conditions many of the producing countries have seriously set about making definite provisions for the future. If countries like the United States find it necessary to undertake the organized practice of forestry as a measure of self-protection, how much more necessary is it for Porto Rico to do so? The Philippines, too, maintain a technical forest organization, which

¹ Previous attempts to provide a forest administration were made in the Regulations for the Payment of Fees to the Technical Personnel of Public Works, Mines, Forests, and Telegraphs of the Island of Porto Rico, issued 1879, which provided, among other things, for the "inspection of forests for the formation of plans for their use." The Political Code for Porto Rico of 1902 (sec. 134) provides for "a chief of lands and forests which shall have charge of all matters relating to lands and forests." Neither of these laws, however, yielded any tangible results.

not only cares for their vast resources, but is undertaking the reforestation of the grassy wastes which have resulted from the same destructive agricultural practices that have devastated the Porto Rican forests, "conuco" cultivation. Hawaii for the last 10 years has maintained an active forest organization which has given special attention to watershed protection, and, although one-fourth of the total land area is still forested and largely permanently reserved and carefully protected, has done much forest planting besides. In fact, forest planting has been carried on by private enterprise in Hawaii for nearly a generation.

There is no country of all of these more favorably situated than Porto Rico to undertake the practice of forestry. Local market conditions can hardly be equaled anywhere. The forest soils are generally well isolated, and well and centrally located, and are thus admirably adapted to serve easily and at a minimum of expense the general needs of the surrounding population, at the same time affording protection to the headwaters of the more than a thousand streams of the island.

NEEDED LEGISLATION.¹

Laws concerning the forests and trees are no new thing to Porto Rico. Mention has previously been made of the early land laws, which required tree planting as a condition of the grant; of the "Law of Waters," providing for the study of the watersheds which it was advisable to keep wooded; of the "regulations" of 1879 concerning public works, which provided an apparently elaborate forest administration intrusted with "the inspection of forests for the formation of plans for their use"; and lastly to the provision in the Political Code of 1902 for a "chief of lands and forests." It is not known that these various works and officials ever existed except on paper, but certainly no tangible results from them have come down to the present day.

More recently, by the act of March 9, 1911, the legislative assembly created a Board of Commissioners of Agriculture² which has interested itself in forestry. The supervisory machinery is thus already in existence and its interest in the work already aroused.

¹ A forestry law was drafted along the lines discussed in these pages for inclusion herein as an appendix. It was, however, omitted as the bulletin was going to press and referred instead to the committee recently created by joint resolution [J. R. No. 3, approved April 3, 1916] of the legislative assembly "for the study of the forestry needs of Porto Rico." This committee is composed of the President of the Board of Commissioners of Agriculture, the Commissioner of the Interior, the Commissioner of Education, and the Special Agent in Charge of the Porto Rico Agricultural Experiment Station at Mayaguez.

² The president ex officio is a head of department designated by the governor. Of the other six members one must be a member of the House of Delegates and be designated by the speaker, while each of the commercial associations—Asociacion de Puerto Rico, Asociacion de Productores de Azucar, Asociacion de Productores de Cafe, Asociacion de Productores de Tabaco, and Asociacion de Productores de Frutas—nominate one of the five remaining commissioners.

It is now only necessary to have the designation and powers of the board¹ extended to include the subject of forestry.

The law giving the board charge and direction of forestry work should also provide the technical machinery for carrying it into effect. A provision of first importance is one creating the position of insular forester and defining the qualifications for this office so as to insure the work being developed under a forester not only of liberal technical training but of practical experience as well. It is also essential to make the office strictly nonpolitical. This can best be done by setting a high standard of technical qualifications and making the incumbent subject to removal only upon his failure to measure up to the standard set or because of improper conduct. The position would thus come virtually under the classified civil service, as is the case in the Federal Forest Service. The insular forester would have immediate charge, direction, and control of all forestry matters, subject to the supervision and approval of the board.

Much requires to be done in a scientific way to learn the distribution, properties, and habits of the various trees suitable for forest planting and management. It would therefore be advisable to provide for the establishment of a forest experiment station. Here, in addition to other work, forest tree nurseries could be maintained and experimental tree planting done. In connection with such a station an arboretum might be developed where all the different trees of the island could be set out. Such an experimental garden would be of immense educational value. The data and experience of the station staff should be made available to the public through publications and lectures and cooperation with landowners in carrying on forestry work.

The insular government has at different places scattered over the island tracts of vacant land, much of which is now idle and unproductive, and generally located in out-of-the-way places. Some of it will always be most profitably utilized for growing timber. It would accordingly be extremely desirable to have all of these tracts carefully examined with the view to determining their adaptability to forest or agricultural use. As much as is unquestionably best suited to the growth of a forest cover or is not now available for other uses could very profitably be reserved for demonstration and experiment, permanently or otherwise as circumstances might warrant. Lands so reserved might very properly be constituted Insular Forests, and the power to set them aside by proclamation be reposed in the governor. After their creation they ought to be subject to the exclusive control of the insular forest service, which would have

¹ An amendment would also be desirable providing for a longer term for each of the five commissioners nominated by the different associations, the terms to be so arranged that not more than two would expire in any one year. This would insure a greater stability and continuity in the controlling policy and provide a long enough term to make it worth while for a member to familiarize himself with the work of the board.

the right to make and enforce all necessary rules and regulations for their protection and management, and to sell or lease under limited permit any products or uses.

In justice to a municipality in which an insular forest might be located, provision ought to be made that it receive a certain percentage of any revenue of such forest as recompense for loss in taxable income caused by the presence of tax-free government land. This method has been adopted by the Federal Government in reimbursing States on account of National Forests. A second method which aims to accomplish the same purpose and is now in effect in some of the States is for the State to pay to the county or town in which a State forest may be located a fixed sum annually, generally from 1 to 4 cents an acre, in place of taxes exempted from these lands.

During the first few years the work of the insular forest service would yield only such revenue as could be realized from the sale of seeds or seedlings which it seemed desirable to the board to dispose of. After the organization of the insular forests there would be some revenue from leases and other special uses, and later on a regular income from the mature timber. During the formative period, at least, it would be extremely desirable to cover into the insular treasury all revenues from forestry sources, to be constituted a special fund available for expenditure for any forestry purpose.

It is desirable to make the law as comprehensive as possible at the outset in order to outline in advance the full scope and significance of the work. The initial annual appropriations need, however, provide for only the few essentials required to get the work under way. An appropriation of \$5,000 should be sufficient to cover the salary of the forester, his necessary field and office expenses, and the hire of any assistants he may need for nursery and investigative work. When it comes to establishing the experiment station, a special building and equipment fund of \$10,000 will be necessary and an additional maintenance fund of \$3,000 annually.

There are other considerations than those concerned strictly with forestry which merit legislative attention. The regulation of the indiscriminate and nomadic cropping of ground provisions and the equally indiscriminate practice of charcoal burning are of first importance. The most permanent and logical means are education and the definite establishment of land titles. A cadastral survey of the island has been repeatedly urged by the principal government officials, both present and past, who have come in contact with the land situation in any of its phases. The difficulties in levying taxes and in knowing what are and what are not government lands have already been mentioned. The further difficulty, and the one with which we are particularly concerned here, is the enforcing of the police powers against unlawful trespass on both public and private property. It is obvious that it must be known with certainty who

owns land before it becomes possible to enforce trespass laws with any degree of assurance. The establishment of the bounds of each man's lawful property by survey would remove this present difficulty and many others.

A temporary expedient to meet the "conuco" and the charcoal situation is to require a license. In the case of the "conuco" it would only be possible to carry out a definite plan of licenses or permits with respect to the public lands. In the case of charcoal burning the method of regulation employed in Martinique offers a favorable means of control. This law¹ provides in brief that before a man can manufacture any charcoal he shall declare his intention at the mayor's office and state also where he is to make it and in what quantity. The vendor of charcoal other than the manufacturer must also have a license. To secure such license the vendor must present a certificate from the mayor showing that the manufacturer has complied with the requirements of manufacture. Parties transporting charcoal for their own use or that of another must have a certificate from the police or mayor giving the residence of the person from whom it was bought, his license number, and the number and residence of the buyer. Retailers are prohibited from buying their supplies in other than the regular markets of the island, and appropriate penalties are provided for violating any of these provisions. Such a law as this properly enforced in Porto Rico would go a long way toward preventing indiscriminate charcoal burning.

THE LUQUILLO NATIONAL FOREST.

Upon the transfer of the island to American sovereignty the Spanish Crown lands in the Sierra de Luquillo² became the property of the Federal Government. Originally supposed to aggregate some 40,000 acres³ and to embrace a considerable amount of practically virgin forest land which was rapidly being cut and destroyed, these lands were constituted the Luquillo Forest Reserve (now National Forest), by presidential proclamation January 17, 1903.⁴ Recently completed surveys covering all but a small part of the central mountain area, however, indicate a reduction in acreage to not over 15,000 acres, including probably the entire "hurricane hardwood" type. Thus the timber producing possibilities of a considerable portion of the area are not very promising, judging from present knowledge of conditions. Nevertheless, for the present at least, these lands will be retained in public ownership and whatever forest growth there may be on them will be protected.

¹ A digest of this law has been referred to the committee mentioned in the note, p. 52.

² For forest description of this region see p. 31.

³ Based on official records in the archives of the Division of Public Lands, Department of the Interior, Porto Rico.

⁴ The recommendation that this be done was made by Dr. Walter H. Evans, Chief of Division of Insular Stations, States Relations Service, U. S. Department of Agriculture, while the exploratory survey upon which the boundary proclamation was based was made by Mr. O. W. Barrett, at that time Botanist of the Porto Rico Agricultural Experiment Station.

APPENDIX I.

TREES OF PORTO RICO.

By W. D. BRUSH, *Scientific Assistant*, and LOUIS S. MURPHY, *Forest Examiner, Forest Service*; and C. D. MELL, *formerly Assistant Dendrologist, Forest Service*.

INTRODUCTORY NOTE.

Much has been published concerning the flora of Porto Rico, yet little of it is available for general use, particularly concerning the trees. Hill in his bulletin on the Forests of Porto Rico (Bul. 25, Forest Service) listed some 60 different kinds of trees, and the woods of 15 of these were described by Sudworth. The work of Gifford and Barrett (Bul. 54, Forest Service, "The Luquillo Forest Reserve, Porto Rico") has already been referred to.

As to arrangement and nomenclature particularly, the principal reliance in preparing this present compilation has been Ignatius Urban's *Symbolæ Antillanæ Seu Fundamenta Floræ Indiæ Occidentalis*. Scientific equivalents have been given only in cases where they appear to be in well-established popular usage, as, for example, *Roystonia borinquena* for *Oreodoza caribaea*.

Acknowledgment is also due to the authors of the above-mentioned Forest Service bulletins, Cook and Collins (Economic Plants of Porto Rico), W. Harris (The Timbers of Jamaica), John T. Rae (West Indian Timbers), and numerous other authorities for descriptive data concerning the uses of the wood and other products of the trees listed. Special acknowledgment is due to Miss J. S. Peyton for painstaking work in the preparation of the index and comparing the spelling of both common and scientific names in the final copy of the manuscript with the original authorities.

The microscopic descriptions of wood structure of the species marked with an asterisk, thus (*8. *Chlorophora tinctoria*) are based on examination by Messrs. Mell and Brush of wood samples in the Forest Service wood collection.

It has been the intention of the authors to include all erect woody plants which attain a height of 15 feet or over, including the tree cactuses and opuntias. The heights and diameters, it should be remembered, represent the extreme sizes which the species have been reported to attain, and are thus often considerably larger than those commonly met with. For convenience in reading, the technical wood descriptions, the less important species, and all but the most common exotic species have been subordinated to the general text. Little-known species and species and genera of very minor importance have been combined where possible and subordinated into notes, yet for completeness have been included.

Following is a synopsis showing the families represented, 57 in all, and the number of genera and species in each family. The genera total 172 and the species 292:

Family.	Genera.	Species.	Family.	Genera.	Species.	Family.	Genera.	Species.
Palmae.....	4	5	Malpighiaceae....	1	2	Thymelaeaceae..	1	2
Juglandaceae.....	1	1	Euphorbiaceae....	9	11	Rhizophoraceae..	2	2
Ulmaceae.....	1	1	Anacardiaceae....	4	5	Combretaceae....	5	5
Moraceae.....	6	9	Aquifoliaceae....	1	2	Myrtaceae.....	5	13
Polygonaceae.....	1	8	Celastraceae.....	1	1	Melastomataceae.	4	10
Nyctaginaceae....	1	1	Staphyleaceae....	1	1	Araliaceae.....	2	3
Magnoliaceae.....	1	2	Sapindaceae.....	5	6	Myrsinaceae....	1	2
Anonaceae.....	4	9	Sabiaceae.....	1	2	Sapotaceae.....	7	17
Lauraceae.....	6	17	Rhamnaceae.....	1	2	Ebenaceae.....	2	2
Hernandaceae....	1	1	Elaeocarpaceae..	1	1	Symplocaceae....	1	5
Cappariaceae.....	1	2	Malvaceae.....	2	3	Styracaceae....	1	1
Brunelliaceae.....	1	1	Bombacaceae.....	4	4	Oleaceae.....	1	1
Rosaceae.....	2	3	Sterculiaceae....	1	2	Apocynaceae....	2	2
Leguminosae.....	22	30	Ternstroemiaceae	3	5	Barraginaceae..	1	6
Zygophyllaceae...	1	2	Guttiferae.....	4	5	Verbenaceae....	5	6
Rutaceae.....	4	14	Bixaceae.....	1	1	Bignoniaceae....	3	6
Simarubaceae....	2	2	Winteraceae....	2	2	Rubiaceae.....	11	16
Burseraceae.....	3	3	Flacourtiaceae..	3	8	Caprifoliaceae..	1	1
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DESCRIPTION OF SPECIES.

I. PALMÆ.

1. *Inodes causiarius* Cook. Yaray; Porto Rican hat palm (Br. W. I.).
Inodes glauca Urb. Damm. Palma de sombrero; Hat palm (Br. W. I.).

Two palms more or less common on the western end of the island, usually along the shore on the coral sand. The leaves are held in high repute in Porto Rico for making hats, immense quantities of which are manufactured every year. The center of this industry is at Joyua, just south of Mayaguez.

2. *Oreodoxa caribaea* (Spreng.) Damm. & Urb. (= *Roystonea borinquena* Cook? = *O. regia* Bello?). Palma real, Yagua, Palma de yaguas, Palma costa, Palma de grana; Palmacte, Pumu (Sp. W. I.); Royal palm (Br. W. I.).

Tree from 40 to more than 80 feet high and sometimes 2 feet in diameter, found throughout the island, the West Indies, and southern Florida. One of the most conspicuous objects in the Porto Rican landscape. The most useful part is the sheathing base of the leaf called "yagua," which is used for roofing and siding of huts, and for a great variety of other purposes, especially by the poorer classes. The outer portion of the trunk is used for boards, posts, poles, piles, etc. The leaves are used for thatching roofs. The royal palm has more economic uses than any other tree in the West Indies.

3. *Acrista monticola* Cook. Palma de la Sierra, Palma de Sierra, Yagua del Monte.

Tree from 30 to 80 feet high and from 12 to 18 inches in diameter, closely allied to the royal palm (*Oreodoxa caribaea*). The Porto Rican species is confined chiefly to the mountain regions. The outer portion of the trunk, split into boards, is used for making huts, and the leaves for thatching roofs.

4. *Cocos nucifera* L. Palma de coco, Coco, Cocotero (Sp. W. I.); Coconut, Porcupine wood, Coco palm (Br. W. I.).

Tree usually from 40 to 50 feet tall and from 12 to 15 inches in diameter, found everywhere along the coast in Porto Rico, the West Indies, and the Tropics generally. Extensively planted and of great economic importance. The "milk" of green fruit is in great demand locally. It is drunk directly from the nut, which is then thrown away. The ripe fruit is exported in large quantities. The wood is used for walking sticks, umbrella handles, posts, piles, and for other purposes requiring strong and durable material. The fiber of the husk, known as coir, and the dried meat of the nut, known as copra, both important articles of export from the East Indies to Europe, have no commercial value in Porto Rico.

The wood is somewhat similar to that of the royal palm, very hard, heavy (about 50 pounds per cubic foot), strong, tough, and very durable in contact with the soil.

II. JUGLANDACEÆ.

5. *Juglans jamaicensis* C. DC. Nogal, Palo de nuez; Jamaican or West Indian walnut (Br. W. I.).

Tree from 40 to 80 feet high and from 18 to 24 inches in diameter, occurring only at high altitudes on the island. The wood is similar to that of our native Butternut (*Juglans cinerea* L.) but is seldom used except occasionally for furniture.

III. ULMACEÆ.

6. *Trema micranthum* (L.) Bl. Palo de cabra, Guacimilla, Guazymillo; Ixpepe (Mexico).

Tree from 15 to 60 feet high, occurring here and there throughout the island. Wood little used. Wood light brown, moderately fine grained, capable of a good polish, but rather soft, light, and weak. Pores small, isolated, or in groups of two to five or more, and evenly distributed. Pith rays minute, inconspicuous.

IV. MORACEÆ.

7. *Trophis racemosa* (L.) Urb. Ramon,¹ Ramoncillo.

Tree from 30 to 50 feet high, occurring in the northwestern part of the island, chiefly of importance on account of the leaves, which are used as fodder for cattle and horses. Its wood is good for all purposes except in exposed situations.

*8. *Chlorophora tinctoria* (L.) Gaudich. Mora, Palo de mora, Fustic.

Tree from 45 to 65 feet high and from 18 to 24 inches in diameter, occurring mostly in the southwestern part of the island. The wood is used locally for shelving in country houses and for spokes of wheels; also for furniture and wherever great strength and durability are required. This tree, which occurs throughout the West Indies and Central America, furnishes one of the most important dyewoods of commerce.

Wood ² a handsome brownish-yellow, very fine-grained. Pores small, isolated or in groups of two to four, more or less connected by short wavy tangential lines of wood parenchyma, which are conspicuous on a transverse surface. Pith rays very narrow and inconspicuous. Wood takes a fine polish, hard, heavy (about 44 pounds per cubic foot), strong, tough, and durable.

*9. *Artocarpus incisa* L. (= *Artocarpus communis* Forst.). Pana, Palo de pan, Castaña; Bread fruit, Bread nut (Br. W. I.).

Tree from 40 to 60 feet high, introduced from the East Indies, now growing spontaneously in many parts of the island, particularly the north side. The fruit is very large with numerous large seeds resembling the Spanish chestnut, whence the common name "castaña." These seeds are an important article of native food. Wood, though little used, is said to be highly appreciated for furniture and for building houses.

Wood is yellowish-gray in color; rather light and soft, but strong, resistant, and elastic. Its specific gravity is given as 0.495 (C. & C.).

10. *Pseudolmedia spuria* (Sw.) Griseb. Negra lora.

Tree from 25 to 50 feet high with a limited distribution on the island. It is of very little use except for fuel and charcoal.

*11. *Ficus lævigata* var. *lentiginosa* subvar. *subcordata* (Warb.) Urb. (= *F. lentiginosa* Vahl.). Jagüey, Jiguerillo, Lechesillo.

Tree from 30 to 60 feet high and from 4 to 5 feet in diameter, occurring quite generally in the mountainous regions. It is at first semiepiphytic and often destroys, trees on which it grows. It is used in making fishing canoes.

Wood light gray with narrow brown lines of softer tissue, fine, and straight-grained moderately soft and light (about 30 pounds per cubic foot). Pores small, solitary or in groups of two to four, evenly distributed. Tangential lines of wood-parenchyma fibers visible on a smooth transverse surface. Pith rays very narrow and indistinct.

NOTE.—Similar to the above in the uses and properties of their wood are *Ficus sintonisii* Warb. (Jagüey, Higuillo preto) and *Ficus stahlitii* Warb. (Hagüey, Jagüey) trees, 15 to 60 feet high, which occur in the mountainous regions. Several other species of *Ficus* known locally as "Higuero" are reported as being generally distributed throughout the island. These are small trees averaging from 10 to 20 feet high and from 4 to 6 inches in diameter. The wood, which is very little used, is white, soft, light (about 43 pounds per cubic foot), and not strong nor durable in the soil.

Another species *Ficus nitida* Thumb. (Laurel de India, Laurel), introduced from Asia, is a beautiful tree from 45 to 65 feet high and has been planted on the island for ornamental purposes. The wood is not used.

¹ This tree must not be confused with the bread-nut tree (*Brosimum alicastrum* Sw.), which is also called "Ramon" throughout the West Indies and Yucatan. The latter is a native of Jamaica but has not been reported from Porto Rico.

² See pp. 12-14, Forest Service Circular 184.

12. *Cecropia peltata* L. Yagrame hembra, Llagrume, Trumpet tree; Guarumbo, saruma (Mexico).

Tree from 20 to 60 feet high and from 10 to 12 inches in diameter, occurring in mountainous regions. It is common throughout the West Indies. The trunks and branches are hollow and are often made into carrying poles and floats for fishing nets. Wood white, light, soft, moderately weak, and not durable in contact with the soil.

V. POLYGONACEÆ.

- *13. *Coccoloba rugosa* Desf. Ortegon.

Tree from 40 to 100 feet high, occurring from sea level to 2,000 feet elevation, abundant along the coast. Wood useful for construction timber. Wood purplish, fine-grained, hard, heavy, strong, and tough. Pores very small, isolated or in groups of two or three, evenly distributed. Pith rays narrow, inconspicuous.

- *14. *Coccoloba uvifera* (L.) Jacq. Uvero, Uva del mar, Sea grape.

Tree from 15 to 30 feet high and from 3 to 4 feet in diameter, growing along the coast. The trees are reproduced by cuttings. The wood is highly esteemed for cabinet work. Wood dark brown with nearly black linear markings, very fine-grained, taking an excellent polish, very hard, heavy (65 pounds per cubic foot), strong, and tough. Pores very few, very small, isolated or in radial rows of two to four. Pith rays narrow, inconspicuous.

- *15. *Coccoloba grandifolia* Jacq. Moralon.

Tree from 50 to 60 feet high and from 1 foot to 2 feet in diameter, occurring in mountain forests. Reported formerly very common in the vicinity of Lares and throughout the limestone belt from Ciales and Utuado to the west coast. It is also native to others of the West Indies and to Mexico and Guiana. Wood was highly prized for building purposes and for furniture and cabinet work, but is now scarce.

Wood reddish, close and sometimes cross-grained, very hard, and heavy. Pores minute, isolated, or in groups of two or three, evenly distributed. Pith rays minute, very inconspicuous.

NOTE.—Other species of this genus are **Coccoloba nivea* Jacq. (Calambrefías); *Coccoloba laurifolia* Jacq. (Uvillo, Cucubano, Gateado, Glateado, Uverillo); *Coccoloba obtusifolia* Jacq. (Uvillo); *Coccoloba diversifolia* Jacq. (Palo bobo); *Coccoloba urbaniana* Lindau. (Ortegon). Trees from 15 to 45 feet high, growing mostly in the mountains, and yielding fine and useful timbers. Wood in general similar to the above.

VI. NYCTAGINACEÆ.

16. *Pisonia subcordata* var. *typica* Heimerl. Corcho, Palo bobo.

Tree from 40 to 60 feet high, occurring here and there throughout the island. Wood of very little use.

VII. MAGNOLIACEÆ.

- *17. *Magnolia splendens* Urban. Laurel sabino, Laurel savino, Laurel, Sabino.

Tree from 50 to 100 feet high and from 1½ to 2½ feet in diameter, found in all parts of the island, though now very scarce. One of the most valuable timbers on the island, and used for beams, boards, and furniture.

Wood clear olive-brown, often turning yellowish-green, beautiful, aromatic, straight and fine-grained, resembling the wood of tulip poplar (*Liriodendron tulipifera* L.) and cucumber tree (*Magnolia acuminata* L.) with which it is closely allied. It is moderately hard, heavy, strong, tough, and very durable in contact with soil and air. Does not warp or check during seasoning. Pores very small, solitary or in pairs, and evenly distributed throughout the annual rings of growth, which are marked by more or less distinct narrow lines of radially compressed wood fibers. Pith rays very narrow, scarcely visible on a polished radial surface.

NOTE.—*Magnolia portoricensis* Bello (Burro, Mauricio) recognized by Bello as a separate species is a tree from 45 to 80 feet high. It is reported only from the western part of the island. Wood similar to that of *M. splendens*.

VIII. ANONACEÆ.

18. *Oxandra lanceolata* (Sw.) Baill. Haya prieta; Black lancewood, True lancewood (Br. W. I.).

Tree from 20 to 30 feet high and from 8 to 12 inches in diameter with a limited occurrence in the western part of the island. It occurs largely throughout the West Indies, and in parts of South America where the wood is highly esteemed for lances, fishing rods, shafts, spars, ramrods, and general turnery.

Wood yellow, very fine-grained, hard, light, strong, and very elastic. Pores are minute, solitary or in groups of two to five, radially disposed, and evenly distributed. Pith rays narrow, scarcely visible to the unaided eye.

19. *Oxandra laurifolia* (Sw.) A. Rich. Yaya, Yaya blanca, Haya blanca, Purio; White lancewood (Br. W. I.).

Tree from 30 to 80 feet high and from 10 to 20 inches in diameter. It occurs in the mountain forests and is distributed throughout the West Indies. It is used largely for the same purposes as the true lancewood (*Oxandra lanceolata*), but is not so valuable.

Wood light yellowish and fine-grained, hard, light, and strong. Pores minute, solitary or in small groups, and evenly distributed. Pith rays inconspicuous.

20. *Guatteria blainii* (Griseb.) Urb. Haya, Haya minga, Negra lora.

Tree from 30 to 60 feet high, quite generally distributed throughout the island.

- *21. *Anona muricata* L. Guanábana; Soursop (Br. W. I.).

Tree from 10 to 35 feet high and from 6 to 12 inches in diameter, extensively cultivated throughout the island for the sake of its fruit, which has an agreeable slightly acid flavor, and is closely allied to the East Indian species (*Anona squamosa* L.). Wood of little use except for fuel.

Wood light brown, turning darker with age, fine and straight-grained, resembling somewhat the wood of our papaw (*Asimina triloba* Dunal.), which is called "*Anona*" in Spanish. It is soft, light, not strong, brittle, not durable in contact with the soil. Pores very small, solitary, or occasionally in pairs, and very evenly distributed throughout the annual rings of growth, which are scarcely visible to the unaided eye. Pith rays numerous and indistinct.

22. *Anona palustris* L. Cayul, Cayur, Anon, Corazon cimarron, Cayures, Corcho; Alligator apple, Cork wood (Br. W. I.).

Tree from 20 to 30 feet high and from 8 to 12 inches in diameter. It grows usually in swampy localities and is found along the coasts. Wood used for rafts, floats for fishing nets, and as stoppers for bottles. Wood gray or light brown, somewhat tinged with green, lustrous, fine and straight-grained, soft, very light, weak, not durable in contact with the soil, resembling that of the papaw (*Asimina triloba* Dunal.). Pores small, solitary or in small groups, and evenly distributed. Pith rays scarcely visible to the unaided eye.

23. *Anona squamosa* L. Anón, Anonde escamas, Chirimoya, Cherimolia; Sweetsop; Sugar apple (Br. W. I.).

Tree from 10 to 20 feet high. An East Indian species, introduced into all tropical countries, and now extensively cultivated for its fruit. It is found in most parts of the island. The wood is of little use. Wood light brown streaked with yellow, fine-grained, moderately soft, light, weak, brittle, and not durable in contact with the soil.

NOTE.—Of the other two species found on the island, *Anona reticulata* L. (Corazon; Custard apple, Bullock's heart [Br. W. I.]) is a tree from 15 to 30 feet high and from 6 to 12 inches in diameter, extensively cultivated throughout the island for the sake of its fruit, *Anona montana* Macf. (Guanávana cimarrona), which attains a height of from 30 to 50 feet, occurs chiefly in mountainous regions. The wood of both is similar to that of the other species and is of little use except for firewood.

24. *Rollinia mucosa* (Jacq.) Baill. Anon; Lancewood (Br. W. I.).

Tree from 30 to 50 feet high and from 8 to 12 inches in diameter, of limited occurrence in Porto Rico. Indigenous also to several islands in the Lesser Antilles, to Trinidad, and to Mexico. The wood is said to be occasionally used as a substitute for the true lancewood (*Oxandra lanceolata*), which it resembles. Wood light yellow, moderately hard, heavy, strong, and tough.

IX. LAURACEÆ.

25. *Persea americana* Mill (= *P. gratissima* Gaertn.). Aguacate, Avocate, Avocado; Alligator pear, Butter pear (Br. W. I.).

Tree from 30 to 40 feet high and from 12 to 18 inches in diameter introduced from Mexico and now growing spontaneously throughout the island. It is widely planted throughout tropical and subtropical regions for its edible pear-shaped fruit. The fruit yields an abundance of oil for burning and for soap making. A deep indelible black juice used for marking linen is obtained from the seeds. The wood is suggested for use in cabinetmaking.

Wood light reddish-brown, beautifully figured and fine grained, soft, light (about 40 pounds per cubic foot), and brittle. Pores small, numerous, isolated or in groups of two or three, evenly distributed throughout the annual rings of growth, which are only faintly visible. Pith rays very minute and inconspicuous.

NOTE.—*Persea krugii* Mez. (Canela) is reported as a tree from 30 to 50 feet high, with a very limited occurrence on the island. Wood similar to that of the above.

***26. *Phoebe elongata* (Vahl.) Nees. Avispillo, Laurel, Laurel bobo, Laurel geo-geo.**

Tree from 30 to 60 feet high and from 1 foot to 2 feet in diameter, from the Luquillo region. Wood light brown, fine, and cross-grained, taking a good polish; hard, heavy, strong, and tough. Pores very small, evenly distributed. Pith rays very narrow and inconspicuous.

NOTE.—*Phoebe montana* (Sw.) Griseb. (Laurel, Avispillo), another species of this genus is of limited occurrence in the interior of the island and is similar in size and in the character of its wood.

27. *Ocotea*.

A genus of limited occurrence and little known uses in Porto Rico, is represented by the six following species: *Ocotea wrightii* (Meissn.) Mez. (Canela, Canelon); *Ocotea moschata* (Meissn.) Mez. (Nemoca, Nuez moscada, Nuez moscada cimarrona, Nuez moscada del pays, nutmeg); *Ocotea cuneata* (Griseb.) Urb. (Sassafras, Laurel sassafras); *Ocotea floribunda* (Sw.) Mez. (Laurel); *Ocotea leucoxydon* (Sw.) Mez. (Cacaillo, Laurel, Laurel bobo, Laurel geo, Laurel geo-geo); *Ocotea portoricensis* Mez. (Laurel, Laurel avispillo, Laurel geo). Trees from 30 to 90 feet high and from 1 foot to 3 feet in diameter, occurring in mountain forests. The wood resembles that of *Phæbe elongata*.

28. *Nectandra*.

The following five species of this genus are reported from Porto Rico: *Nectandra sintenisii* Mez. (Laurel, Laurel amarillo, Laurel blanco, Laurel geo, Laurel macho); *Nectandra krugii* Mez. (Laurel, Laurel canelon); *Nectandra membranacea* (Sw.) Griseb. (Laurel, Laurel geo-geo, Laurelillo); *Nectandra patens* (Sw.) Griseb. (Laurel, Laurel roseta); *Nectandra coriacea* (Sw.) Griseb. (Avispillo, Laurel). Trees from 30 to 70 feet high, occurring mostly in the mountains of the Luquillo region, and relatively unimportant. Wood light brown. Pores small, isolated or in groups of two or three, evenly distributed. Pith rays minute, inconspicuous.

29. *Hufelandia pendula* (Sw.) Nees. Aguacate cimarron, Cedro macho, Laurel, Palo colorado.

Tree from 50 to 60 feet high and from 1 foot to 1½ feet in diameter, occurring in mountainous regions. Wood yellowing-brown turning darker with exposure to air and light. It is fine and straight-grained, hard, moderately heavy, strong, and tough. Pores numerous, small, and evenly distributed. Pith rays narrow and inconspicuous.

30. *Acrodictidium salicifolium* (Sw.) Griseb. Canela, Canelillo.

Tree from 25 to 50 feet high. Common in the mountainous districts, but of slight economic value.

X. HERNANDIACEÆ.

31. *Hernandia sonora* L. Mago.

Tree from 30 to 60 feet high, with a limited occurrence in the mountains of the Luquillo region. Wood little used. Wood cream colored, fine-grained, rather soft and light. Pores visible to the unaided eye, isolated or in groups of two to six, often more, evenly distributed.

XI. CAPPARDIACEÆ.

32. *Capparis portoricensis* Urb. Burro, Burro blanco.

Tree from 45 to 60 feet high, found near the southern coast. Wood white or light yellow, fine-grained, taking a good polish, moderately hard and heavy. Pores small, isolated or in groups of two to four, evenly distributed. Pith rays narrow, inconspicuous.

NOTE.—*Capparis jamaicensis* Jacq. (Burro, Palo de burro Prieta), is reported as a shrub or tree from 10 to 50 feet high, occurring along the coast. Wood similar to the preceding.

XII. BRUNELLIACEÆ.

33. *Brunellia comocladifolia* H. & B. Palo bobo.

Tree from 45 to 60 feet high, of limited occurrence in the mountainous region of the island.

XIII. ROSACEÆ.

34. *Prunus occidentalis* Sw. Almendron, Almendrillo.

Tree from 40 to 50 feet high and from 1 foot to 2 feet in diameter, common throughout the island. Wood employed, like the black cherry (*Prunus serotina*), for cabinet work and interior finish of houses.

Wood light brown, fine and straight-grained, taking an excellent polish, and often difficult to distinguish from light-colored mahogany. It is hard, heavy (about 66 pounds per cubic foot), strong, moderately tough, and very durable under water. Pores small, numerous, evenly distributed throughout the annual rings of growth, which are easily seen on a smooth transverse section. Pith rays moderately narrow and easily visible under the hand lens.

35. *Hirtella*.

Two species are reported from Porto Rico: *Hirtella tiandra* Sw. (Teta de burra) and *Hirtella rugosa* Pers. (Teta de burra cimarron, Icacillo).

Described as shrubs or small trees ranging from 20 to 50 feet high and from 6 to 12 inches in diameter, occurring throughout the island, chiefly in mountainous regions. The wood is used principally for fuel and charcoal. Wood light brown, turning darker with age, fine and straight-grained, hard, heavy, strong, tough, and moderately durable in the soil.

XIV. LEGUMINOSÆ.

*36. *Inga vera* Willd. Guava, Gauba.

Tree from 30 to 50 feet high growing in mountainous region and extensively planted for shade in coffee plantations, for which it is considered the most important tree in Porto Rico. Wood used only for fuel and charcoal.

Wood light gray, fine grained, moderately hard, heavy (40 pounds per cubic foot), and strong. Pores small, isolated or in groups of two or three, evenly distributed and sometimes connected tangentially by the wood-parenchyma fibers surrounding each pore. Pith rays minute, inconspicuous.

*37. *Inga laurina* (Sw.) Willd. Guamá.

Tree from 30 to 50 feet high, abundant in the foothills, and very valuable as a shade tree in coffee plantations, being considered only second to *Inga vera* for this purpose. Wood used for firewood and charcoal.

Wood dark gray, fine-grained, moderately hard, and heavy (44 pounds per cubic foot). Pores small, isolated or in groups of two or three, evenly distributed, and often connected by tangential lines of wood-parenchyma fibers. Pith rays minute very inconspicuous.

*38. *Pithecolobium saman* (Jacq.) Benth. Saman, Guango; Rain tree (Br. W. I.).

Cultivated tree from 45 to 60 feet high, occurring sparingly throughout the island. Native of Central and South America. Excellent for shade in yards and along roadsides, as well as in pastures where through the property of its roots to accumulate and store nitrogen in the soil it is also beneficial to the grass crop. It yields pods very suitable for food for cattle. It is believed to be superior to the bucare (*Erythrina*) as a shade for nutmeg, cacao, coffee, tea, and similar crops because less liable to fall and injure the plantation. It is especially well adapted for planting in dry arid regions. In Central America the wood is used to make wheels for oxcarts.

Wood red, fine-grained, taking a good polish, fairly hard and heavy, not durable. Pores moderately small, isolated or in groups of two to four, evenly distributed surrounded by wood parenchyma which sometimes forms tangential lines. Pith rays small, inconspicuous.

NOTE.—*Pithecolobium arboreum* (L.) Urb. (Cojoba, Cojobana) is reported as being a tree from 45 to 60 feet high and about 18 inches in diameter, occurring in many parts of the island. The structure of the wood is similar to that of *P. saman*.

*39. *Albizia lebeck* (L.) Benth. Acacia amarilla, Amor platónico, Flamboyán; East Indian walnut, Siris tree, Woman's tongue (Br. W. I.).

Beautiful cultivated tree from 30 to 40 feet high, drought resisting, and planted in the southern part of the island. Native of the East Indies. Has no economic uses in Porto Rico, but elsewhere the wood is used for house and boat building, furniture, sugar-cane crushers, etc., while the gum, as an adulterant of gum arabic, is used in calico printing.

Wood dark brown, lustrous, and rather cross-grained, resembling our black walnut (*Juglans nigra* L.) in appearance and finish, takes a good polish, seasons and works well, is hard, heavy (about 48 pounds per cubic foot), moderately strong, and durable. Pores small, isolated or in groups of two or three, evenly distributed and more or less surrounded by wood parenchyma. Pith rays small, inconspicuous.

40. *Acacia nudiflora* Willd. Cojoba, Cojobana, Tamarindo cimarrón, Acacia nudosa.

Tree from 25 to 50 feet high and about a foot in diameter, with a limited distribution on the east coast. Wood brown, tinged with red, somewhat coarse and straight-grained, taking a good polish. It is hard, heavy, strong, moderately tough, and durable. Pores rather large and arranged in more or less irregular tangential rows visible on smooth transverse surface.

NOTE.—Another species, *Acacia riparia* H. B. K. (Zarza), is reported as quite generally distributed on the island. It attains at times a height of 45 feet and has a wood similar to the above.

*41. *Leucaena glauca* (L.) Benth. Acacia palida, Hediondilla; Ipil-Ipil (Philippine Islands).

Tree from 25 to 30 feet high and sometimes a foot in diameter, quite common throughout the island and tropical America generally. The tree is especially well adapted for reforestation of grassy wastes because of the ease with which it establishes itself in competition with the grass sod and its rapid growth. Wood used locally for making tools, handles, etc.

Wood brownish, tinged with red, rather coarse and straight-grained, taking a good polish. It is hard, heavy, strong, tough, and very durable. Pores rather large, solitary, and evenly distributed. Pith rays very narrow and indistinct.

42. *Adenanthera pavonina* L. Coralitas, Mato, Mato colorado, Palo de mato, Peronilas.

Tree seldom more than 30 feet high, introduced from the East Indies, and growing spontaneously in many places. The wood resembles red sandalwood (*Pterocarpus*) and is used for making a red dye. The seeds when crushed and mixed with borax make an adhesive substance. Wood used for house building and cabinetmaking.

Wood takes a good polish and is hard, heavy, strong, and durable. Pores moderately large, solitary, and surrounded by abundant wood parenchyma, which occasionally forms tangential lines. Pith rays very numerous and inconspicuous.

***43. *Piptadenia peregrina* (L.) Benth.** Cojobana, Cojoba, Cojobillo, Cojobo.

Tree about 60 feet in height and about a foot in diameter, quite generally distributed on the island. In central and South America it grows to be a very large tree, yielding valuable timber known as "yoke," but in Porto Rico no uses have been recorded except for fuel and charcoal.

Wood dark reddish-brown, close-grained, hard, heavy, strong, tough, and very durable.

44. *Stahlia monosperma* (Tul.) Urb. Cobana negra, Cóbana, Cóbano, Polisandro.

Tree from 20 to 30 feet high and about a foot in diameter, found chiefly along the coast and watercourses. The wood is much used for making furniture, also for railroad ties for the cane roads. Wood is black, hard, heavy, strong, and tough.

***45. *Hymenaea courbaril* L.** Algarrobo, Courbaril, Quapinole jutahy, Jatoba; Locust tree (Br. W. I.).

Tree from 30 to 90 feet high, with a diameter of from 4 to 6 feet, well distributed throughout the island. The wood is used largely for the cogwheels of sugar mills, for wagon wheels, in carpentry, and especially for cabinet work and fine furniture. A resin, known as American copal, resina copal, and courbaril obtained from this tree is used as a medicament and for ornaments. The fruit is sometimes used as food.

Wood, red with light and dark streaks; sapwood lighter, beautiful, somewhat resembling mahogany, very fine grained, capable of a high polish, hard, heavy (about 64 pounds per cubic foot), tough, durable (except when placed underground), and seasons well. Pores moderately small, isolated or in groups of two to four, evenly distributed, surrounded by wood parenchyma, which often connects them tangentially. Annual rings of growth clearly visible. Pith rays small, scarcely visible to the unaided eye on a smooth transverse surface.

***46. *Tamarindus indica* L.** Tamarindo; Tamarind (Br. W. I.).

Tree from 20 to 60 feet high, very common throughout the island, and widely cultivated in the Tropics for the acid pulp of its fruit. It is a beautiful ornamental tree, well adapted for roadside planting. Its leaves, bark, seeds, and flowers all have medicinal and other useful properties. Probably native to tropical Africa. The wood is highly esteemed for the handles of tools, as axes and hoes, is sometimes used for building purposes, and is said to furnish excellent charcoal for the manufacture of gunpowder.

Wood light yellow, fine and cross grained, hard, heavy (about 59 pounds per cubic foot), tough, elastic, and very durable. Pores moderately small, isolated or in groups of two or three, evenly distributed, often connected by conspicuous tangential lines of wood parenchyma. Pith rays minute, very inconspicuous.

47. *Bauhinia kappleri* Sagot. Flamboyán blanco, Seplina, Varietal.

Tree from 30 to 50 feet high, introduced from Asia. Grows spontaneously in many parts of the island. Wood used for fuel and sometimes for making small articles of furniture. Wood brownish in color and very handsome, fine grained, and takes a beautiful polish.

***48. *Cassia fistula* L.** Cañafistula.

Cultivated tree from 20 to 60 feet high and about a foot in diameter, a native of tropical Asia, and very common over the entire island. Wood is used for fuel, the bark for tanning, and the pulp of the pods medicinally. Wood of a reddish color, hard, heavy (about 60 pounds per cubic foot), strong, tough and durable.

***49. *Cassia grandis* L.** Cañafistula cimarrona.

Cultivated tree from 40 to 60 feet high and from 1 foot to 1½ feet in diameter, occurring mostly in the southwestern part of the island, found to some extent in a wild

state. Wood used for carpentry and cabinetwork. Wood reddish-brown, handsome, fine and straight grained, taking a high polish, hard, heavy (about 51 pounds per cubic foot), strong, and durable.

***50. *Hæmatoxylum campechianum* L.** Palo de Campeche, Campeche; Logwood.

Tree from 20 to 40 feet high and 6 or more inches in diameter, occurring in the western part of the island chiefly along the coast and throughout tropical America. It is occasionally planted on the island for its wood, the logwood of commerce, which is used in making dyes.

Wood blood red, very fine and cross grained, taking a very high polish, hard, heavy, strong, tough, and very durable.

51. *Poinciana regia* Boj. Flamboyán, Flamboyán colorado; Flame tree (Br. W. I.).

Cultivated tree from 45 to 60 feet high, found mostly in the western part of the island. Native of Madagascar. It is a beautiful ornamental shade tree very common in the West Indies and widely planted throughout the Tropics. Wood little used.

Wood white, moderately fine grained, taking a good polish, but soft, light, and not strong. Pores small, isolated or in groups of two or three, evenly distributed. Tangential lines of wood-parenchyma fibers very prominent. Pith rays minute, very inconspicuous.

52. *Ormosia krugii* Urb. Palo de mato, Mato, Peronia.

Tree from 30 to 80 feet high, with a limited occurrence throughout the island. The wood is used only for charcoal. Wood very light, soft, and inferior.

53. *Sesbania grandiflora* (L.) Pers. Gallito, Báculo, Cresta de gallo.

A tall shrub or small cultivated tree from 10 to 30 feet high, quite generally planted over the island. Probably a native of the East Indies. The wood is used for poles, posts of native houses, and firewood. Parts of the tree are used medicinally and as food. Wood white, soft, light, and not durable. Pores of medium size, isolated or in groups of two to five, evenly distributed. Pith rays small, indistinct.

***54. *Pictetia aculeata* (Vahl.) Urb.** (= *P. aristata* P. DC.). Tachuelo, Hachuelo.

Tree from 15 to 30 feet high, found chiefly in the southern and eastern coastal regions. The wood is often used in native house construction for underpinning, shingles, and shelving, and for cabinet work. It becomes with age extremely hard, so that it will turn the edge of almost any woodworking tool. It is somewhat used for fuel, but the charcoal burner avoids it because of the effect upon his ax.

Wood dark brown, fine, and straight grained, taking a very high polish, extremely hard, heavy, strong, tough, lasting almost indefinitely in contact with the soil. Pores rather small and connected by numerous fine tangential lines, which are visible only under a hand lens on a smooth transverse surface.

55. *Pterocarpus officinalis* Jacq. Palo pollo, Palo de pollo.

Tree from 75 to 90 feet high and from 1 foot to 2 feet in diameter, found chiefly in swampy localities in Porto Rico, but more generally distributed in other parts of the West Indies and Central America. Wood is used for fuel.

Wood light brown or rusty colored, fine and straight grained. It does not take a very high polish and is soft, light (about 35 pounds per cubic foot), weak, brittle, and not durable in contact with the soil.

56. *Lonchocarpus*.

This genus is represented in Porto Rico by three species which are of but slight economic importance. *Lonchocarpus latifolius* (W.) H. B. K. (Palo Hediondo, Forte Ventura), a tree occasionally 60 feet high found in many parts of the island. The wood, sometimes used locally for furniture, is reddish with occasional dark or black streaks. *Lonchocarpus domingensis* (Pers.) P. DC. (Geno-geno), and *Lonchocarpus glaucifolius* Urb. (Geno), tree from 15 to 45 feet high with a limited distribution in the western part of the island. Wood used for fuel.

*57. *Piscidia piscipula* (L.) Sarg. Ventura.

Tree often 60 feet high and about 2 feet in diameter. It has a very limited occurrence along the shores of the island. Wood is light yellow-brown, very fine and straight grained, taking a very good polish, hard, heavy (about 54 pounds per cubic foot), strong, tough, and very durable in contact with the ground. Pores rather large, not numerous, and surrounded by softer tissue which is clearly visible in transverse surface as numerous tangential bands.

58. *Andira jamaicensis* (W. Wr.) Urb. Moca, Moca blanca; Cabbage tree (Br. W. I.); Bastard cabbage-bark, Angelin (Jamaica).

Tree from 30 to 60 feet high and from 12 to 30 inches in diameter, quite generally distributed in the forests throughout the island. The wood is very suitable for piles, bridges, boat construction, the hubs of wheels, flooring, and all kinds of carpentry work. Its most common use in Porto Rico is for the framework of country houses. The wood is imported into Europe and this country for walking sticks and umbrella and parasol handles and for the turned parts of cabinetwork.

Wood reddish-yellow with dark streaks, cross and coarse-grained, capable of a high polish, hard, heavy (from 47 to 55 pounds per cubic foot), strong, tough, and especially durable in water. Pores moderately large, isolated or sometimes in groups of two to four, evenly distributed, and connected by tangential branching lines of wood-parenchyma fibers. Pith rays narrow, indistinct.

59. *Erythrina*.

A genus represented in Porto Rico by two native and one introduced species. Of the native species *Erythrina corallodendron* L. (Bucare, Piñon espinoso; Red bean tree [Jamaica]; Coral wood, Arbol madre [Mexico]) is a shrub or small tree from 10 to 20 feet high, found chiefly on limestone hills, while *Erythrina glauca* Willd. (Bucago) is from 30 to 40 feet high, with a limited occurrence, usually along rivers. Both species occur quite generally throughout tropical America. Their wood is made into corks, floats for fishing nets, light ladders, etc., and is light in color, coarse-grained, corky, soft, light, and weak. Pores of medium size, isolated or in groups of two or three, evenly distributed. Pith rays easily distinguishable on a smooth transverse surface. *Erythrina micropteryx* Poepp. (Bucare, Palo de boyo; Bois immortelle, Madre de cacao [S. Am.]) is a tree from 45 to 60 feet high, cultivated in many localities on the island, mostly on coffee plantations, for its shade. Indigenous in Peru. Wood soft, similar to the other two species.

XV. ZYGOPHYLLACEÆ.

*60. *Guajacum officinale* L. Guayacán, Lignum-vitæ.

Tree from 30 to 60 feet high and from 12 to 18 inches in diameter, occurring chiefly along the southern coast. The wood is highly esteemed for its wearing qualities, and is widely used for pulleys, rollers for casters, wooden cogs, mortars, hubs for wheels, and wherever great strength and hardness are required.

Wood dull yellowish-brown with dark olive-brown streaks, very fine, close and cross grained, greasy to the touch, takes a fine polish, and is extremely hard and heavy (about 85 pounds per cubic foot), very tough, and durable. Pores minute, isolated, and easily distributed. Pith rays minute and very inconspicuous.

NOTE.—Another species said formerly to have been abundant by now of only limited occurrence along the south coast is *Guajacum sanctum* L. (Guayacán blanco, Guayacancillo), a shrub or tree from 30 to 45 feet high, having a wood similar to that of the preceding.

XVI. RUTACEÆ.

61. *Fagara*¹ *martinicensis* Lam. Cenizo, Espino, Espino rubial, Ayua; Prickly ash (Br. W. I.).

Tree from 40 to 80 feet high and from 1 foot to 3 feet in diameter, found in the mountain forests throughout the island. The wood is used for furniture and cabinetwork and also for house building. The bark contains a dye.

¹ *Fagara* = *Zanthoxylum*.

Wood light yellow, fine and straight grained, taking a very beautiful polish, hard, heavy (60 pounds per cubic foot), strong, somewhat brittle, and not considered durable for outside work. Pores small, solitary or sometimes grouped in twos and threes. Pith rays very narrow and scarcely visible under the hand lens.

*62. *Fagara flava* (Vahl.) Kr. et Urb. Satinwood, Yellow wood (Br. W. I.).

Tree from 10 to 30 feet high and from 10 to 12 inches in diameter with a limited distribution in the southwestern part of the island. The wood is used for veneering, cabinetwork, and furniture. It is too valuable for structural purposes. It was formerly exported as a substitute for the true satinwood (*Chloroxylon swietenia* DC.) of India.

Wood light yellow, but darkening with age. It has a satiny luster on a longitudinal surface, where it shows when polished a beautiful rippled pattern. It is hard, heavy (about 60 pounds per cubic foot), strong, and moderately tough. Structure of wood similar to the preceding.

NOTE.—Other species of this genus in Porto Rico are *Fagara caribæa* Krug et Urb. (Espino Rubial), a tree from 30 to 60 feet high; *Fagara monophylla* Lam. (Carubio, Mapurito, Rubia, Espino, Espino Rubial); and *Fagara trifoliata* Sw. (Espino Rubial), trees from 10 to 30 feet high, each commonly occurring in the foothills and south coast regions.

63. *Ravenia urbani* Engl. Tortugo Prieto.

Tree from 30 to 50 feet high, of rare occurrence, reported only from the high forest region of the Sierra de Luquillo.

64. *Amyris maritima* Jacq. Tea, Palo de tea.

Tree from 15 to 30 feet high and from 4 to 8 inches in diameter, growing in thickets near the sea. It is very suitable for furniture, and splinters are used as torches by the natives. It is especially useful in exposed situations.

Wood light yellow, with a spicy odor, very fine-grained, and oily to the touch. It takes a fine polish and is hard, heavy, strong, and durable. Pores minute, isolated or in groups of two to twelve, sometimes more, evenly distributed. Pith rays very small and inconspicuous.

*NOTE.—Another species of but slight importance in Porto Rico is *Amyris balsamifera* L. (Tea; rosewood or torchwood [Jamaica]), a tree from 15 to 20 feet high, with whitish wood very similar in properties and uses to *A. maritima*.

*65. *Citrus aurantium* L. China dulce, Naranja China; Sweet orange (Br. W. I.).

A cultivated tree from 15 to 40 feet high and occasionally nearly a foot in diameter. A native of southern Asia, it has been widely introduced throughout the Tropics. It is planted everywhere on the island and to some extent grows spontaneously. The wood is much used for making walking sticks, in cabinetwork, and for knickknacks of various sorts. The fruit varies widely in quality and size, but the best of it is heavy and juicy and has a fine flavor.

Wood light yellow, close and straight grained, taking a beautiful polish, hard, heavy (about 55 pounds per cubic foot), very strong, tough, and durable. Pores very small, numerous, and more or less evenly distributed. Numerous fine tangential lines of soft tissue visible on a smooth transverse surface under the hand lens. Pith rays very narrow, numerous, and inconspicuous.

NOTE.—The principal horticultural varieties also cultivated for their fruit, some of which are to be found growing in the semiwild state, are: *Citrus bigaradia* Loisel (Naranja; Sour orange [Br. W. I.]); *Citrus decumana* L. (Toronja, Pomelo, Grapefruit); *Citrus hystrix*, subsp., *acida* (Roxb.) Bonavia (Lima, Lime); *Citrus limonum* Risso (Limón, Lemon); *Citrus medica* L. (Toronja, Cidra, Citron, Citrus limetta, Bergamota, Limon dulce, Sweet lemon).

¹ See pp. 10 and 11, Forest Service Circular 184, "Fustic Wood: Its Adulterants."

XVII. SIMARUBACEÆ.

*66. *Simaruba tulæ* Urb. Aceitillo; West Indian satinwood (Br. W. I.).

Tree from 20 to 50 feet high and from 12 to 18 inches in diameter, occurring in mountain forests from the Luquillos to Maricao. It is reported formerly to have been plentiful on the limestone uplands north of Lares, in association with moralon and capa blanca, and to have been cut into lumber for building purposes. Now so scarce as to be no longer of any importance. Elsewhere in tropical America it is considered one of the rarest and most expensive ornamental woods for furniture and interior finish, being so much sought after that the stumps are often dug up and cut into veneer.

Wood light yellow, very fine, and often wavy-grained, taking a high polish, hard, heavy (about 55 pounds per cubic foot), strong, and durable. Pores small, isolated or in groups of two or three, evenly distributed. Pith rays narrow, not visible to the unaided eye.

67. *Picramnia pentandra* Sw. Guarema, Hueso, Hueso prieto, Palo de hueso.

Tree from 15 to 35 feet high and from 15 to 25 inches in diameter, occurring quite generally on the island. Wood used in house building.

Wood dark colored, fine grained, taking a good polish, hard, and very heavy (about 76 pounds per cubic foot). Pores small, isolated or in groups of two or three, evenly distributed. Pith rays narrow, inconspicuous.

XVIII. BURSERACEÆ.

68. *Tetragastris balsamifera* (Sw.) O. Kuntze. Masa, Masa colorado, Palo de aceite, Palo de masa; Copal (Guatemala).

A common forest tree from 20 to 70 feet high and from 16 to 20 inches in diameter, found in the mountainous parts of the island. This tree yields a very desirable wood for interior work of houses.

Wood rose-colored or yellowish, beautiful, fragrant, and fine-grained, moderately hard, light, strong, and very durable. Pores small, isolated or in groups of two to four, evenly distributed. Pith rays small, inconspicuous.

69. *Dacryodes excelsa* Vahl. Tabanuco, Tabonuco; Candle wood (Br. W. I.).

A tree from 60 to 75 feet high and from 3 to 5 feet in diameter, found quite generally in the mountainous regions, especially in the Luquillos, where it often occurs in large stands. One of the most valuable trees on the island for lumber, because of its large size, straightness of bole, and occurrence in close, pure stands. A resin obtained from the gum is used extensively by the natives for candles and torches, as incense, and medicinally. The wood is used for flooring, ceiling, etc., and is often stained and sold as mahogany.

Wood brown, sometimes cross and fine grained, often giving a "satiny" appearance. It is similar in physical properties to our yellow poplar (*Liriodendron tulipifera* L.), lumber dealers of this country placing them in the same class. Tabanuco is, however, handsomer and finer grained than yellow poplar and capable of a higher polish. It is moderately hard, heavy, strong, and not durable when exposed. Pores small, solitary, or in groups of two or two or three, and evenly distributed. Pith rays small, inconspicuous.

*70. *Bursera simaruba* (L.) Sarg. (= *B. gummiifera*, Jacq.). Almácigo; Gumbo limbo, West Indian birch (Br. W. I.).

Tree from 20 to 40 feet high, very common on the island. This is the largest tree of the chaparral forests on the limestone hills of the south side of the island. Like the jobo (*Spondias lutea*), it is readily propagated from cuttings, even from stakes of large size. It is therefore used for "live" fence posts and is one of the commonest trees to be seen along the roadside, where it also serves, though poorly, for the purpose of shade. The wood is of little value.

Wood light brown, often with dark discolorations, fine grained, very soft, spongy, light, weak, and very liable to decay. Pores numerous, small, isolated or in groups of two or three, sometimes more. Pith rays very inconspicuous.

XIX. MELIACEÆ.

- *71. *Cedrela odorata* L. Cedro, Cedro hembra; West Indian cedar; Spanish cedar; Cigar-box cedar (Br. W. I.).

Tree from 50 to 100 feet high and from 4 to 6 feet in diameter, formerly common to all parts of the island, but now rare except in the inaccessible places. Spanish cedar is one of the most highly esteemed woods in the West Indies and is used for more purposes than any other. Its principal use, however, is for cigar boxes.

The wood is pale reddish-brown, but varies considerably from very light to very dark, depending upon the age and the kind of soil in which it grows. It has a general appearance similar to that of mahogany and possesses a characteristic fragrant odor. It is moderately soft, light (about 30 pounds per cubic foot), rather strong, somewhat tough, and very durable in contact with the soil. Pores are rather large, not numerous, solitary, or often in small groups distributed evenly throughout the wood. Pith rays few, narrow, and indistinct to the naked eye.

- *72. *Swietenia mahagoni* Jacq. Caoba; Mahogany (Br. W. I.).

Tree from 50 to 100 feet high and from 3 to 5 feet in diameter. This tree has not been reported from Porto Rico by recent botanical explorers. There is some evidence, however, that mahogany occurred at one time on the island. It is the most highly esteemed wood for furniture and interior finish. No other wood has such a wide range of uses and so many substitutes.

Wood light or dark brown, with a very pleasing appearance when polished. It is fine and cross grained, works rather easily, hard, heavy (varies from 35 to 67 pounds per cubic foot), strong, tough, and very durable. Pores are moderately large, often filled with white or brown substance (tyloses), and arranged singly or in small groups; pith rays inconspicuous to the unaided eye.

- *73. *Melia azedarach* L. Alilaila, Lilaila, Pasilla; China berry (Br. W. I.).

Tree from 20 to 50 feet high and from 8 to 15 inches in diameter, cultivated and growing spontaneously in various parts of the island, including the Cordillera Central and the limestone formation of the western and southwestern coast. This tree has been introduced from Asia and is now very common throughout tropical and sub-tropical parts of the world for shade and ornament. The wood is sometimes used by the country people for tool handles and the like.

Wood mahogany colored, with a coarse and straight grain, moderately soft, light, weak, and not durable in contact with the soil. Pores rather large in early wood, which render the boundary of the annual rings of growth usually very conspicuous; the pores in the late wood are much smaller and inconspicuous.

*NOTE.—An umbrella variety of the alilaila, *Melia azedarach umbraculifera* Sarg. (Umbrella China tree, China berry (Br. W. I.)), which was developed in Texas in about 1880, is planted in Porto Rico merely for shade and ornament. The wood has characteristics similar to the one above.

- *74. *Guarea trichilioides* L. Guaraguao, Acajou; Musk wood (Br. W. I.).

Tree from 40 to 80 feet high and sometimes 6 feet in diameter. It occurs in mountain forests from the Luquillos to Maricao and is one of the leading woods of the island, being very highly prized by the natives. Because of the great demand it is now rather scarce. Its principal uses locally are for strong wagons and carriages, farm implements, and general carpentry. The wood resembles mahogany and Spanish cedar and is useful for the same purposes.

Wood light reddish-brown, sometimes streaked with lighter and darker shades, hard, moderately heavy, strong, tough, and very durable in contact with the soil. It has in a general way the appearance of dark-colored mahogany and an odor resembling musk. Pores small, very numerous, and connected by fine tangential lines of softer tissue which are scarcely visible to the unaided eye. Pith rays very narrow, numerous, and inconspicuous.

*NOTE.—Another and little-known species of this genus is *G. ramiflora* Vent. (Guaraguaillo, Guaraguao macho), a tree usually under 25 feet and rarely

60 feet high, occurring in the forests, widely distributed, but not plentiful, throughout the uplands from the Luquillos to Mayaguez. Wood similar to the one above.

75. *Trichilia*.

Three species of this genera occur in Porto Rico: *Trichilia pallida* Sw. (Caracolillo, Gaita, Ramoncillo, Cabo de hacha); *Trichilia hirta* L. (Cabo de hacha, Guaita, Jobillo, Molinillo, Palo de anastasio, Retamo, Guayavacón); and *Trichilia triacantha* Urb., trees from 15 to 60 feet high, occurring principally in the mountainous regions of the island and to some extent in the limestone hills of the south coast. Wood, though very similar to that of *G. trichilioides*, is seldom used except for fuel.

XX. MALPIGHIACEÆ.

*76. *Byrsonima spicata* (Cav.) L. Cl. Rich. Maricao.

Tree from 20 to 60 feet high and from 18 to 24 inches in diameter, occurring quite generally in forests throughout the island. The wood is used for furniture and house building. The bark is astringent and is used for tanning.

Wood dull reddish brown, moderately fine grained, taking a good polish, moderately hard, heavy, and strong. Pores small, isolated or in groups of two or three, evenly distributed. Pith rays narrow, inconspicuous.

*77. *Byrsonima lucida* (Sw.) L. Cl. Rich. Palo de doncella, Sangre de doncella.

Tree from 20 to 30 feet high, quite widely distributed on the island. The wood is highly esteemed for furniture and interior finish. Wood dark brown, very fine grained, taking a good polish, moderately hard, heavy, and strong. Pores minute, isolated, or in groups of two or three, evenly distributed. Pith rays very narrow and inconspicuous.

XXI. EUPHORBIACEÆ.

78. *Phyllanthus*.

Two species of this genera are found in Porto Rico, one a native (*Phyllanthus nobilis* var. *antillanus* (Juss.) Müll. (Amortiguado, Avispillo, Higuerrillo, Higuillo, Millo, Palo de millo, Siete-cueros [mas.], Yaquillo [fem.]) is a tree from 30 to 60 feet high, widely distributed on the island; the other *Phyllanthus distichus* (L.) Müll. (Grosella, Grosella blanca, Cerezas, Cereza amarilla, Otaheite gooseberry), introduced from India, is a tree from 15 to 30 feet high, cultivated for the sake of its fruit. Wood of both is but little used, although very beautiful, white, hard, strong, and tough.

*79. *Drypetes lateriflora* (Sw.) Kr. et Urb. Varital; Florida or Guiana plum, White-wood (Br. W. I.).

Tree from 20 to 30 feet high and from 5 to 10 inches in diameter, found principally near Bayamon. It is also common in southern Florida and on the islands of the West Indies. Wood rich dark brown, very fine and cross grained, hard, heavy (about 58 pounds per cubic foot), not strong, brittle, and liable to check in drying. Pores small, solitary, or in short radial rows, with numerous very fine tangential lines of softer tissue present. Pith rays very numerous and inconspicuous.

80. *Drypetes alba* Poit. Cafeillo, Hueso, Palo de vaca blanco.

Tree from 15 to 60 feet high found in the mountain forests of the Sierra de Luquillo and Cordillera Central. The wood is often used for hubs of wheels, and also for fuel and charcoal.

Wood light yellow, with irregular, thin, yellowish-brown streaks, fine and cross grained, taking a high polish, hard, moderately heavy, strong, tough, and difficult to split. Pores rather small, solitary or in short interrupted radial rows, evenly distributed. Pith rays very narrow, but plainly visible on a smooth surface under the hand lens.

NOTE.—Another species of this genera of slight importance, yielding a wood of inferior quality which is seldom used except for fuel and charcoal, is *Drypetes glauca* Vahl. (Palo blanco, Cafeillo, Varital, Palo de aceituna), a tree from 20 to 50 feet high and from 1 to 2 feet in diameter, generally distributed throughout the mountain forests and somewhat in the woodlands along the south coast. It is also common throughout a number of the islands of the West Indies. The wood is of inferior quality.

81. A group of unimportant genera of this family, each represented by a single species, comprises *Hieronymia elusoides* (Tul.) Mull. (Cedro macho), a tree from 45 to 100 feet high, occurring in the western parts of the island. Native also to other of the West Indies. There are no recorded uses for the wood nor descriptions of its characteristics. *Alchorneopsis portoricensis* Urban. (Palo de gallina), tree from 30 to 50 feet high, known only from the Luquillo, and central regions of the island. It yields a soft wood of little use. *Alchornea latifolia* Sw. (Achiotillo, Palo de cotorra, Yobiillo), a tree from 25 to 60 feet high, quite widely distributed, yielding a wood with properties similar to that of Palo de gallina. *Sapium laurocerasus* Desf. (Hinchahuevos, Lechesillo, Manzanillo, Tabeiba), a tree from 15 to 50 feet high, widely distributed in mountainous regions on the island.

*82. *Aleurites moluccana* (L.) Willd. (= *A. triloba* Forst.). Nuez, Nuez de India; Candleberry tree, Candlenut, Indian walnut (Br. W. I.).

Tree from 20 to 40 feet high. Introduced from tropical Asia and the South Sea Islands and planted here and there throughout Porto Rico. It is useful mainly for shade throughout the Tropics and for the nuts it bears, which are called "kukui" nuts in the Sandwich Islands. Wood little used.

Wood very light yellow, soft, light, weak, and not durable in contact with the soil. Pores small, isolated or in groups of two to five, radially disposed, and evenly distributed. Pith rays minute and very inconspicuous.

*83. *Hippomane mancinella* L. Manzanillo, Machineel.

Tree from 15 to 50 feet in height, occurring in the coastal regions. It has a poisonous acid sap which necessitates considerable care being taken in felling and in thoroughly seasoning the wood before working. The wood is suitable for furniture and is used largely for veranda floors and weatherboarding because of its durability when exposed.

Wood yellowish brown, with darker stripes, beautiful, slightly fragrant, straight and very fine grained, resembling in general appearance and texture the boxwood of commerce (*Buxus sempervirens* L.). It takes a high polish, is hard, varies from light to heavy (from 36 to 50 pounds per cubic foot), strong, tough, very durable, and very easy to work; in all these qualities this wood resembles mahogany. The pores are minute, numerous, solitary, and evenly distributed. Pith rays minute, scarcely visible to the unaided eye on a radial surface.

84. *Hura crepitans* L. Javillo, Molinillo, Havillo, Havarilla; Sand-box tree, Monkey's dinner bell (Br. W. I.).

Tree from 20 to 50 feet high and from 1 foot to 2½ feet in diameter, introduced from South America. It is planted extensively throughout the island for shade, because of its spreading crown. The acid irritant sap necessitates careful felling and seasoning of the wood before working. The wood is valued locally for making canoes and for interior work in houses. In some parts of the West Indies the trunks are often hollowed and used extensively for holding cane sugar.

Wood very light brown, with darker brown stripes, fine and straight grained, taking a fine polish. It is soft, light (about 31 pounds per cubic foot), extremely brittle, and is said to resist the action of water. Pores very small and evenly distributed throughout the annual rings of growth. Pith rays very inconspicuous.

XXII. ANACARDIACEÆ.

*85. *Mangifera indica* L. Mango.

A cultivated and sparingly naturalized tree from 30 to 50 feet high and from 12 to 18 inches in diameter, native of southern Asia or the Malay Archipelago. It yields a very common but highly prized fruit of the Tropics, comparable in quality and value with the apple or the orange, though entirely different from either in texture and flavor. The wood is useful for the same purposes as our common ash (*Fraxinus*), gunstocks, tool handles, window frames, etc.

Wood grayish brown, fine grained, hard, heavy (about 50 pounds per cubic foot), strong, tough, and elastic. Pores small, isolated or in groups of two to four, evenly distributed. Pith rays narrow, inconspicuous.

86. *Anacardium occidentale* L. Pajuil, Cajuil, Acaju, Marañón; Cashew tree (Br. W. I.).

A wild and cultivated tree from 20 to 40 feet high and from 9 to 12 inches in diameter, occurring in all parts of the island. It is used largely in boat building, for carriage hubs, yokes, and farm utensils. Its principal use in Porto Rico is for charcoal and fuel. The nuts are edible when roasted, and yield oils which are useful for many purposes. An acrid irritant substance contained in the soft shell of the nuts necessitates care in handling them. This is driven off as poisonous fumes in roasting.

Wood pinkish, fine grained, hard, moderately heavy (about 36 pounds per cubic foot), strong, and durable. Pores small, isolated or in groups of two to four, evenly distributed. Pith rays small, inconspicuous.

87. *Spondias mombin* L. (= *S. lutea* L.). Jobo; Hog plum (Br. W. I.).

Tree from 30 to 40 feet high and from 1 foot to 2 feet in diameter. Very common throughout the island, particularly along roadsides. It is much used for stakes and fence posts, which are very durable because they take root and live. It is probably due to this property, as with the almácigo (*Bursera simaruba*), more than to any specially favorable quality as a shade tree that they are so commonly found along roadsides. It is one of the trees commonly pollarded for fuel wood and bears an edible fruit which is much esteemed.

Wood yellowish brown, fine grained, soft, light (about 30 pounds per cubic foot), and moderately strong. Pores small, isolated or in groups of two or three, evenly distributed. Pith rays minute, very inconspicuous.

88. *Spondias purpurea* L. Ciruela, Ciruela del país, Jobillo, Jobo frances; Spanish plum (Br. W. I.).

A tree or shrub from 20 to 30 feet high, occurring in mountainous regions. It is often cultivated for its fruit, which is considered superior to *S. mombin*. Wood in all respects similar to *S. mombin*.

89. *Metopium toxiferum* (L.) Krug. et. Urb. Cedro prieto, Papayo; Poison wood, Hog plum (Br. W. I.).

Tree from 30 to 50 feet high, with a short trunk sometimes 2 feet in diameter. It has a limited distribution in the southwestern part of the island, and occurs throughout the West Indies and on the keys of southern Florida.

Wood rich, dark brown streaked with red, fine and straight grained, resembling the wood of our native sumacs. It takes a fine polish, is easily worked, moderately hard, heavy (about 50 pounds per cubic foot), not strong, and only moderately tough. Pores small, very numerous, and evenly distributed throughout the wood. Pith rays very narrow and inconspicuous.

XXIII. AQUIFOLIACEÆ.

90. *Ilex nitida* (Vahl.) Maxim. (= *I. dioica* Griseb.) Cuero de sapo, Brigueta naranjo, Hueso prieto, Palo de hueso.

Tree from 20 to 60 feet high and from 10 to 15 inches in diameter, occurring in the mountain forests of the Luquillo region and generally throughout the island. The wood is used for fuel and for hut building. Wood light-colored, fine-grained, hard, and heavy.

91. *Ilex sideroxyloides* var. *occidentalis* (Macf.) Loes. Gongolin; Central American oak (Br. W. I.).

Tree from 30 to 50 feet high, occurring in the mountain forests of the Luquillo region. Wood of little use. Wood flesh-colored, hard, and heavy.

XXIV. CELASTRACEÆ.

92. *Elæodendron xylocarpum* var. *corymbosum* (Vahl.) Urb. Cocorron, Coscorron, Guayarote.

Shrub or tree from 10 to 30 feet high, occurring quite generally along the seacoasts of the island. Wood fine-grained. Pores minute, isolated, or in groups of two or three, evenly distributed. Pith rays moderately narrow but conspicuous.

XXV. STAPHYLEACEÆ.

93. *Turpinia paniculata* Vent. Avispillo, Cedro hembra, Eugenio, Lilaililla, Sauco cimarron.

Tree from 30 to 60 feet or more high, occurring in the mountains and waste places. The wood, which is used for fuel and charcoal, is somewhat similar to that of out bladder nut (*Staphylea trifolia* L.).

XXVI. SAPINDACEÆ.

94. *Thouinia striata* Radlk. Ceboruquillo, Guara, Quiebra hacha, Sebuquillo.

Tree from 25 to 65 feet high, occurring generally throughout the island, usually in the drier situations. No uses are reported for the wood, doubtless because of its extreme hardness.

Wood light-colored, very fine-grained, with many fine light lines, giving a pleasing figure. It takes a fine polish and is extremely hard, heavy, strong, and tough. Pores minute, isolated, or in groups of two or three, evenly distributed. Pith rays minute, inconspicuous.

95. *Melicocca bijuga* L. Guenepa, Quenepas; Genip tree, Genipe; Ginep (Br. W. I.).

A cultivated and semiwild tree from 25 to 60 feet high and up to 3 feet in diameter reported from the east, south, and west parts of the island. It is native of tropical America and is found throughout the West Indies. It is cultivated somewhat for its fruit and is also suitable for ornament and for roadside shade. Wood is said to be heavy and hard and useful for all purposes except in exposed situations. No local uses are reported.

- *96. *Cupania*.

There are two species of this genera represented in the tree flora of Porto Rico, namely, *Cupania americana* L. (Guara, Guara blanca), and *Cupania triquetra* A. Rich. (Guara).

Trees from 30 to 60 feet high, quite widely distributed locally, and occurring generally throughout the West Indies. The woods of all are alike and are used largely for posts.

Wood very light brown, with a conspicuous wavy grain. It takes a high polish, is soft, moderately light, and brittle. Pores solitary or in groups of two or three, evenly distributed. Pith rays minute, very inconspicuous.

- *97. *Matayaba domingensis* (DC.) Radlk. Doncella, Tea cimarrona, Raton.

Tree from 30 to 60 feet high and from 8 to 10 inches in diameter, occurring chiefly in Luquillo and central mountain regions. It is found also in the other Greater Antilles. No local uses for the wood are reported.

Wood red, fine and straight grained, taking a beautiful polish and resembling dark-colored mahogany. It is hard, heavy, strong, tough, and very durable. Pores rather large, solitary, and evenly distributed; pith rays are narrow and more or less indistinct except under the hand lens.

NOTE.—Another species *Matayaba apetala* (Macf.) Radlk. (Doncella) is also reported from the same localities. Size and uses are not noted, although in Jamaica it is reported as attaining a height of from 40 to 60 feet and a diameter of 2½ feet and as being a most useful hardwood, suitable for all purposes and especially for exposed situations.

98. *Exothea paniculata* (Juss.) Radlk. (= *Hypelata paniculata* Camb.). Guacáran, Gáita.

Tree from 20 to 30 feet high and from 12 to 18 inches in diameter, occurring in the limestone hills of the western part of the island. Wood used occasionally for cabinet work. Wood white, moderately hard, heavy, and strong.

XXVII. SABIACEÆ.

99. *Meliosma*.

Two species of this genus occur in Porto Rico: *Meliosma obtusifolia* Krug. and Urb. (Guayrote arroyo, Aguacatillo, Cacao bobo, Cacaíllo, Ciralillo, Serillos), and *Meliosma herbertii* Rolfe. (Aguacatillo, Cacao bobo). Trees from 30 to 60 feet high, generally

distributed throughout the mountainous interior from the Luquillos to Maricao and Anasco. Reported also from several other of the West Indies. No local uses for the wood are reported. Pores of wood small, isolated, or in groups of from two to eight or more. Pith rays small, inconspicuous.

XXVIII. RHAMNACEÆ.

- 100.** *Colubrina ferruginosa* Brongn. Abelluello, Abejuelo, Achiotillo, Aguacatillo, Aguaytarán, Guitaran, Quitaran, Mabi, Raton, Sanguinaria; Snakewood, Ironwood, West Indian greenheart (Br. W. I.).

Tree from 30 to 60 feet high and sometimes 2 feet in diameter, quite generally distributed throughout the island. The wood is used for building and occasionally for piling on account of its resistance to decay in water.

Wood light yellowish-brown, very fine and wavy-grained, taking a very good polish, very durable in contact with the soil, hard, heavy (about 60 pounds per cubic foot), strong, and tough. Pores very small, somewhat more numerous in the early wood than in the late wood. Pith rays very narrow and inconspicuous.

*NOTE.—Another species of little economic importance is *Colubrina reclinata* (L'Hér.) Brongn. (Mabi, Palo mabi), a tree 15. rarely 30, feet high from the southwestern part of the island. Wood similar to the preceding.

XXIX. ELOÆCARPACEÆ.

- 101.** *Sloanea berteriana* Choisy. Cacao motilla, Cacao otillo, Cacao roseta, Cacaillo, Motillo.

Tree from 25 to 90 feet high and sometimes over 2 feet in diameter, occurring chiefly in mountain forests. The wood is used locally for fuel and building purposes.

Wood white, taking a high polish, very hard, heavy, strong, tough, and very durable in exposed situations.

XXX. MALVACEÆ.

- ***102.** *Hibiscus tiliaceus* L. (= *Hibiscus elatus* Sw. = *Paritium tiliaceum* A. Juss.) Emmajaqua, Emajagua, Majagua, Mahagua; Blue or mountain mahoe (Br. W. I.); Mahot, Mahot franc (Haiti); Hau (Hawaii).

Tree from 10 to 30 feet high, growing in moist situations, widely distributed throughout the uplands of the island. Common also in the other West Indies and throughout the remaining tropical world. The bark furnishes a strong and flexible fiber comparable to jute, which is often used in making cordage. Nearly all the ropes in Porto Rico are made from this tree. It has also been highly recommended as a raw material for paper making. The wood makes handsome furniture, cabinetwork, and flooring, and is used largely for shingles and railway sleepers.

Wood dark bluish green, with dark and light streaks, (about 47 pounds per cubic foot), straight and fine-grained, taking a fine polish, hard, heavy, beautiful when polished, strong, tough, and very durable. Pores small or in groups of two or three, evenly distributed. Pith rays minute, inconspicuous.

- 103.** *Thespesia populnea* (L.) Soland. Emajaguilla, Palo de Jaqueca, Santa Maria.

Tree from 30 to 60 feet high, occurring on the north and west coasts in moist situations. It is a common tree on the seashore of most eastern tropical countries and throughout the West Indies. The inner bark of the young branches yields a tough fiber which is used for cordage. The wood is little used locally, but elsewhere in the Tropics is used for cabinetwork, building, and a variety of other purposes.

Wood dark brown, tinged with red, beautiful, "satiny," fine-grained, resembling in general appearance our black walnut (*Juglans nigra* L.). It is hard, heavy, tough, and very durable, especially in water. Pores small, solitary, or in groups of two or three, evenly distributed. Pith rays moderately narrow, distinct, clearly visible on a polished radial surface, where they appear as light flecks and give a pleasing appearance.

***104.** *Thespesia grandiflora* P. DC. Maga, Magar, Magas.

Tree from 30 to 45 feet high and from 1 to 3 feet in diameter, occurring quite generally throughout the island. The wood is highly esteemed for furniture, flutes, guitar pegs, etc. It is also used largely for shelving and for foundations, house piling, etc., because of its durability in the ground.

Wood rich chocolate-brown, beautiful, fine-grained, taking a good polish, hard, heavy (42 pounds per cubic foot), strong, and very durable in contact with the soil. Pores solitary or occasionally in groups of two or three, evenly distributed. Pith rays inconspicuous.

XXXI. BOMBACACEÆ.

***105.** *Ceiba pentandra* (L.) Gaertn. (= *Eriodendron anfractuosum* DC.). Ceiba; Silk-cotton, Cotton tree, Kopak tree, Cork wood (Br. W. I.); Fromager (Haiti).

Tree from 60 to 100 feet high and sometimes from 8 to 10 feet in diameter, most common in the south and west coast regions, particularly on limestone soils. It is also widely distributed throughout the Tropics and usually present in open plains and cultivated fields. The wood is used for making boats, dugouts, rafts, tubs, and basins. Boards and shingles are often made of this wood after treating it by immersing the logs in limewater. In West Africa its chief commercial value lies in the "floss" or "kopak"¹ as it is known to commerce, which is a cottony substance surrounding the seeds.

Wood white or light brown, coarse and straight-grained, very soft, light (about 28 pounds per cubic foot), rather strong, and not durable in contact with the soil. Pores large, evenly distributed throughout the annual rings of growth; the latter are not always clearly marked. Pith rays conspicuous.

106. *Quararibea turbinata* (Sw.) Poir. Garrocha, Garrocho, Palo de Garrocha.

A shrub or tree from 25 to 30 feet high, common in all parts of the island.

***107.** *Ochroma lagopus* Sw. Guano, Corcho; Bois Liege (Haiti); Cork wood, Down tree (Jamaica); Balsa wood (of commerce).

Tree from 30 to 60 feet high and 1 foot or more in diameter common on the limestone soils and along the shore directly behind the mangrove in the north and west coast regions and generally throughout the south coast and south slopes of the Central Mountains. Particularly common along the roads. It is a tree of the open country, like the ceiba. The wood, because of its extreme lightness, is sometimes used as a substitute for true cork, for stopping bottles, as floats for fish nets, and for other purposes where a light wood is required. The bark yields a chestnut-brown fiber suitable for rope making, and the seed envelopes yield a soft cotton or down extensively used for stuffing pillows and mattresses and to a limited extent for making into garments. The bark is also used locally for the tannin it contains, and both bark and roots are used medicinally.

The wood is nearly white or slightly tinged with red, showing practically no distinction between heartwood and sapwood. It has a silky texture, loose structure, and soft tissue easily compressible under the thumbnail, and is very fibrous and difficult to work. It is said to be the lightest of all woods, having a specific gravity varying

¹ This floss of the ceiba is exported in large quantities from the East Indies and West Africa; the variety from Java is regarded as a fiber of great merit, and is used for stuffing pillows and sofas. Its lightness, softness, and elasticity render it superior to the best qualities of feathers, wool, or hair. This material has been employed also as a buoyant material for packing life belts and for making hats and bonnets, and has even been suggested for the manufacture of paper and gun cotton. It is too short in staple and too weak to be spun into yarn. Unfortunately the silk cotton from the West Indies is accounted of little value at present, but it only remains for some one to start its collection here and ship it to American markets. It has been estimated that the average yield of silk cotton from a single tree in the West Indies and Mexico is approximately 100 pounds. Many thousands of bales of silk cotton might be collected annually in the West Indies and turned to economic use. In 1907 a little over 20,000,000 pounds of silk cotton was exported from Java and Sumatra, and of this quantity about 3,000,000 pounds were consumed in the United States for a great variety of purposes.

from 0.120 (or about $7\frac{1}{2}$ pounds per cubic foot) to 0.240. Pith rays quite conspicuous on a transverse section; they are also plainly visible on the radial surface and give figure to the wood, resembling the character of beech or sycamore, only they are more numerous.

*108. *Theobroma cacao* L. Cacao.

A cultivated and seminaturalized tree from 12 to 30 feet high occurring locally on the north and west sides of the island. It is native to tropical America and is grown commercially in a number of the West Indies. It is said to grow best under thoroughly tropical conditions of moisture and warmth at or near sea level (below 500 feet). It is commonly grown under the shade of some one of the leguminous trees, usually *Erythrina micropteryx* (or *E. umbosa*).

XXXII. STERCULIACEÆ.

*109. *Guazuma ulmifolia* Lam. (= *Guazuma guazuma* Cock). Guácima, Guácima del norte; West Indian elm, *Guazuma plum* (Br. W. I.).

Tree from 30 to 60 feet high and from 15 to 18 inches in diameter, very common throughout the island, the Antilles generally, and on the continent. Wood used for oars, posts, staves, fuel, and charcoal.

Wood light grayish-brown, fine and straight-grained, rather soft, light (35 pounds per cubic foot), moderately weak but tough. Pores small, solitary or in groups of two or three, rarely more, evenly distributed. Pith rays distinct, but rather inconspicuous, plainly visible on a smooth radially cut surface.

110. *Guazuma tomentosa* H. B. K. Guácima, Guácima del sur; Bastard cedar (Br. W. I.); Orme d'Amerique (Fr. W. I.).

Tree from 45 to 60 feet high and from 1 foot to 2 feet in diameter, very common along the southern coast of the island and distributed quite generally throughout tropical America. In Jamaica the wood is said to be used largely for staves of sugar hogsheads, and the best of the young shoots is used extensively for cordage.

Wood light or grayish-brown, rather fine and straight-grained, fissile, taking a fairly good polish, moderately soft, light, rather tough and durable in exposed situations. Pores small, solitary or in radial rows of from two to three. Pith rays narrow and inconspicuous.

XXXIII. TERNSTROEMICEÆ.

111. Represented in Porto Rico by three genera and five tree species, none of which are commercially important.

These are *Ternstroemia peduncularis* P. DC., from 20 to 30 feet high; *Ternstroemia heptasepala* Krug et Urb., from 15 to 25 feet high; *Ternstroemia luquillensis* Krug et Urb. (Palo colorado), from 30 to 60 feet high; *Cleyera albopunctata* (Griseb.) Krug et Urb. (Teta prieta), from 25 to 30 feet high; and *Haemocharis portoricensis* Krug et Urb. (Maricao, Niño de cota), from 15 to 60 feet high; all common in the Sierra de Luquillo, the second last extending through the Cordillera Central to Maricao.

XXXIV. GUTTIFERÆ.

*112. *Mammea americana* L. Mamey, Mammea; Mammee apple (Br. W. I.).

Tree from 30 to 60 feet high and from 18 to 24 inches in diameter, common in all parts of the island. Its fruit is very highly regarded by the natives and it is very generally planted on this account here and elsewhere throughout the American Tropics. The tree also produces a medicinal gum. The wood is well adapted for house building, posts, and piles.

Wood reddish brown, beautiful, wavy, and fine-grained, taking a good polish, hard, heavy (61 pounds per cubic foot), resinous, and very durable in damp situations. Pores small, solitary, or occasionally in pairs, evenly distributed. Pith rays narrow, very inconspicuous.

*113. *Calophyllum calaba* Jacq. Marias, Palo de Maria; Santa Maria (Jamaica).

Tree from 45 to 60 feet high and from 2 to 3 feet in diameter (in Jamaica said to attain a height of 150 feet and a diameter of 5 feet and over), rather common in the humid north, east, and northwest sections and occasionally along the banks of the streams in the semiarid southcoast region. Common also throughout the West Indies. The wood is said to be greatly prized locally for carpentry work, and for canoes when the trunk is large enough. Elsewhere it has a variety of uses, such as construction work, shipbuilding and heavy machine work, posts, furniture, felloes of wheels, and shingles. Seeds yield an oil said to be used in lamps. Tree is suitable for ornamental planting.

Wood white or reddish in color, hard and durable. Reported to weigh about 46 pounds per cubic foot.

*114. *Clusia rosea* Jacq. Cupey, Palo de Cupey; Balsam Fig; Balsam tree (Br. W. I.).

Tree from 20 to 60 feet high and from 18 to 24 inches in diameter; commonly starts as a parasite on the branches of other trees, although it may start directly on the ground. It is quite generally distributed on the island and throughout the West Indies. The wood is used largely for posts and fuel.

Wood reddish-brown with brown and white streaks, very cross and fine grained, hard, heavy (55 pounds per cubic foot), and durable. Pores small, solitary or in pairs, evenly distributed. Pith rays moderately narrow, distinct, but not conspicuous.

NOTE.—Other incidental and unimportant trees in this and a closely related genus are *Clusia krugiana* Urb. (Cupey, Cupei, Cupeillo), occurring in the Luquillo region, and *Rheedia portoricensis* Urb. (= *Clusia acuminata* Spreng = *Tovomitia elliptica* C. & C.) (Guayabacoa, Sebucán), growing along the seacoasts, shrubs or trees from 10 to 60 feet high, with wood resembling that of *Clusia rosea*.

XXXV. BIXACEÆ.

115. *Bixa orellana* L. Achiote, Achote, Bixa, Biji, Arnatta, Anatto.

Tree from 20 to 30 feet high and about a foot in diameter, occurring in the interior. It is planted in many parts of the island. The wood is little used. A coloring matter extracted from the arillus of the seed is much used locally for coloring rice, soup, etc.; and as the "anatto" of commerce is widely used for coloring cheese, chocolates, and butter, also by varnish makers for imparting a rich orange tinge to some grades of their products.

Wood nearly white in its natural state, but when polished turns slightly yellowish or reddish. On a radial surface it has narrow lines of slightly darker color, which correspond with the annual rings of growth clearly visible in transverse sections. It is very soft, light (about 25 pounds per cubic foot), weak, brittle, and not durable in contact with the soil. Pores rather conspicuous in the early wood, rendering it somewhat coarse and open-grained.

XXXVI. WINTERANACEÆ.

116. Represented by two genera, each with one tree species, neither one of which is of importance.

Winterana canella L. (Barbasco, Wild cinnamon), a tree from 25 to 45 feet high, of rather general distribution along the coast and throughout the West Indies, with a pale, orange-colored, aromatic bark which is used as a tonic; and *Pleodendron macranthum* (Baill.) v. Tiegh. (= *Cinnamodendron macranthum* Baill.) (Chupa gallo, Chupa-callos), a tree from 20 to 30 feet high, from the Sierra de Luquillo, with a white, hard, and heavy wood.

XXXVII. FLACOURTIACEÆ.

117. *Homalium racemosum* Jacq. Tostado, Caracolillo, Cerezo.

Tree from 20 to 60 feet high, quite generally distributed throughout the island. The wood is very useful for building and carpentry.

Wood light-colored, fine-grained, moderately hard, heavy, and strong. Pores minute, numerous, isolated or in groups of two or three, evenly distributed. Pith rays numerous, minute, inconspicuous.

118. *Xylosma*.

Two species very similar as to their wood and uses and neither of any great importance are *Xylosma schwaneckeanum* Krug. & Urb. (= *Myroxylon schwaneckeanum* Krug. & Urb.) (Palo de candela, Palo colorado), and *Xylosma buxifolium* A. Gray (= *Myroxylon buxifolium* Krug. & Urb.) (Roseta), trees from 15 to 35 feet high and 1 foot in diameter, the former found chiefly in the Luquillo region and the latter throughout the southwestern part of the island and the West Indies generally. The wood has no uses except for fuel and charcoal.

Wood light brown, turning darker with age, straight and fine-grained, hard, heavy, strong, tough, and very durable in contact with the soil. Pores numerous, very small, arranged singly or in short radial rows. Pith rays very narrow and inconspicuous.

119. *Casearia*.

Five species attain tree size, namely, *Casearia guianensis* (Aubl.) Urb. (Cafeillo, Cafetillo, Palo blanco), from 15 to 30 feet high; *Casearia bicolor* Urb. (Talantrón, Cotorrerillo?), 45 feet high; *Casearia decandra* Jacq. (Caracolillo, Cereza, Cotorrerillo, Gia mansa, Palo blanco), from 18 to 25 feet; *Casearia arborea* (L. Cl. Rich.) Urb. (Gia verde, Rabojunco, Rabo ratón), from 15 to 45 feet high; and *Casearia sylvestris* Sw. (Cafeillo cimarron, Laurel espada, Sarna de perro), from 25 to 60 feet high.

These trees are most common in the calcareous foothills and along the coast in all parts of the island, except the last two, which are reported well distributed throughout the interior mountains from the Sierra de Luquillo to Maricao and Mayaguez. They are also widely distributed throughout the West Indies, except *C. bicolor*, which is reported only from Porto Rico (Utado).

Wood of *C. guianensis* reported to be yellow, hard, and heavy (about 65 pounds per cubic foot), and to be used for lumber, for building native huts, for fences, and for similar uses.

XXXVIII. CACTACEÆ.

120. Represented in Porto Rico by four genera (one exotic) and eight species (two exotic).

These have an erect form and attain tree proportions, or at least are designated "Pitajaya" (meaning tree-cactus) by the natives, although they do not all have a true woody structure and are consequently not real trees, namely, *Cereus quadricostatus* Bello (Pitajaya, Sebucán), from 6 to 30 feet high; *Cereus triangularis* (L.) Haw. (Pitajaya); *Cereus trigonus* Haw. (= *C. triangularis* Stahl. C. & C.) (Pitajaya), from 3 to 9 feet high; *Cereus peruvianus* (L.) Mill, a continental species from 15 to 25 feet high, occasionally cultivated in gardens; *Pilocereus royeri* (L.) Rümpl. (= *Cereus swartzii* Stahl. C. & C.) (Sebucán), 9 feet high; *Opuntia catacantha* Lk. et Otto, 15 feet high; *Opuntia guanicana* K. Schum. (Tuna), from 12 to 15 feet high; and *Nopalea coccinellifera* (L.) Salm-Dyck (Tuna de España, Tuna mansa), a tropical American and West Indian species 12 feet high, occasionally cultivated in gardens.

Their natural distribution is limited largely to the semiarid south coast region, including the small adjacent islands, as Culebra, etc., though they occasionally are found on the limestone hills along the north side of the island. All, except *C. quadricostatus* and *Opuntia guanicana*, which are strictly local in occurrence, are more or less common to the other islands of the West Indies and tropical America.

XXXIX. THYMELÆACEÆ.

121. *Daphnopsis*.

Two species attain tree size in Porto Rico: *Daphnopsis caribaea* Griseb. (Emajagua de sierra), from 15 to 45 feet high, found chiefly in the Sierra de Cayey and Cordillera Central and widely distributed throughout the West Indies; and *Daphnopsis philippiana* Krug et Urb. (Cieneguillo, Emajagua brava, Emajagua de sierra, Majagua quemadora), from 8 to 25 feet high, occurring throughout the mountains from the Sierra de Luquillo to the Cordillera Central.

XL. RHIZOPHORACEÆ.

- *122. *Rhizophora mangle* L. Mangle, Mangle colorado, Mangle sapatero, Red mangrove (Jamaica).

Tree from 30 to 50 feet high and from 1 foot to 3 feet through, growing in tidewater swamps. Wood used for making hogsheds and for knees and ribs of boats and other small craft, also for charcoal and fuel. The logs are used for posts and piling and occasionally cut into boards for flooring and interior finish.

Wood light red or reddish brown with darker, often nearly black, streaks, fine and cross grained, taking a good polish, very hard and heavy (about 70 pounds per cubic foot), strong and durable. Pores very small, numerous, isolated or in groups of two to five or more, evenly distributed. Pith rays visible to the unaided eye on a smooth transverse surface of the wood.

NOTE.—*Cassipourea*, a closely allied genera, is represented by a single species, *Cassipourea alba* Griseb. (Multa, Palo blanco de la costa, Palo de gongoli, Palo de hueso, Palo de oreja, Palo de toro), a shrub or small tree of from 15 to 30 feet high, with a rather general distribution in various parts of the central mountain area, as well as on the limestone foothills.

XLI. COMBRETACEÆ.

- *123. *Terminalia catappa* L. Almendra, Almendrón; Indian almond (Br. W. I.).

Tree from 30 to 60 feet high and about 2 feet in diameter. This is a species introduced from the East Indies, but naturalized and now a very common tree throughout the West Indies, especially in the lowlands. The wood is similar to mahogany and is used for furniture and house building.

Wood is brownish, coarse and straight grained, taking a beautiful polish, moderately hard and heavy (about 40 pounds per cubic foot), brittle and not strong. Pores of moderate size, evenly distributed, and connected by numerous tangential lines of soft tissue. Pith rays narrow and inconspicuous.

- *124. *Buchenavia capitata* (Vahl.) Eichl. Granadillo; Yellow sanders (Br. W. I.).

Tree from 40 to 80 feet high and from 2 to 3 feet in diameter. This is a very common tree throughout the island. The wood is used for furniture and fancy carpentry work.

Wood fine and often wavy grained, satiny, taking a beautiful polish, moderately hard, heavy, strong, and tough. This wood has a very wavy grain. Pores moderately large, evenly distributed, solitary or sometimes in small groups. Pith rays narrow and inconspicuous.

- *125. *Conocarpus erecta* L. Mangle, Mangle botón, Mangle botoncillo, Mangle colorado.

A shrub or small tree from 6 to 25 feet high, growing in the tidewater swamps. Wood used for making charcoal and for fuel.

- *126. *Bucida buceras* L. Ucar, Ucar blanco, Hucar blanco, Bucaro; Wild olive wood of Jamaica; Bois grisgris (Haiti).

Tree from 30 to 60 feet high and about a foot in diameter. It is found chiefly near the coast. The wood is used for shelves in houses and for mallets, wooden cogs, and shingles. It was formerly used for knees in boat building.

Wood white or ashy brown, fine and cross grained, remotely resembling the wood of American elm. It is hard, heavy, strong, tough, and very durable in water. Pores very small, numerous, occurring solitary, and evenly distributed. Pith rays narrow but distinct.

127. *Laguncularia racemosa* (L.) Gaertn. Mangle blanco, Mangle bobo; White mangrove (Jamaica).

Tree from 20 to 30 feet high, growing in the tidewater swamps. Wood used for making charcoal.

XLII. MYRTACEÆ.

*128. *Psidium guajava* L. Guayava, Guayaba, Guayava pera; Guava (Br. W. I.).

Tree from 15 to 25 feet in height and from 6 to 8 inches in diameter. It is cultivated throughout the island and in the Tropics generally and is well known on account of its fruit. The wood is used for making agricultural implements for structures where strength and elasticity are required, and for posts, fuel, and charcoal.

Wood brownish gray, tinged with red, compact, fine and straight grained, with a mottled and often very beautiful appearance. It is hard, heavy (about 45 pounds per cubic foot), strong, and tough. Pores very small, not numerous, and distributed in rather wide inconspicuous zones, visible only under the hand lens. Pith rays very inconspicuous.

*129. *Amomis caryophyllata* (Jacq.) Krug et Urb. Auzú, Ausú, Guayavita, Limoncillo, Malagueta, Pimienta malagueta; Bayberry tree, Bay rum tree, Wild cinnamon (Br. W. I.).

Tree from 20 to 45 feet high and about 2 feet in diameter, occurring in mountainous parts of the island and throughout the West Indies. The wood is suitable for carpentry, cabinetwork, posts, sills, cogs, rollers, and other millwork, and was formerly exported. The leaves have the taste and odor of lemon, and an essential oil of bay or bay oil is obtained by distillation.

Wood dark, mottled, compact, fine and occasionally cross grained, taking a beautiful polish. It is very hard, heavy (about 60 pounds per cubic foot), strong, tough, and very durable. Pores very small, numerous, evenly distributed throughout the wood. Pith rays very narrow and inconspicuous.

*NOTE.—A variety of this species is also recognized, *Amomis caryophyllata* var. *grisea* (Kiaersk.) Krug et Urb. (Limoncillo, Malagueta, Pimienta), a tree sometimes 50 feet high in mountainous regions, the wood of which is very similar to that of the preceding.

130. *Myrcia*.

The genus is represented in Porto Rico by the following four species, which attain tree size: *Myrcia leptoclada* P. DC. (Guayabacón, Guayavacón); *Myrcia splendens* (Sw.) P. DC. (Rama menuda, Hoja menuda); *Myrcia?* *pagani* Krug et Urb. (Ausú); and *Myrcia deflexa* (Poir.) P. DC. (Cieneguillo, Guayavacón).

Trees from 15 to 60 feet high, found in the mountainous regions of the island. The wood is used very little except for fuel and charcoal. Wood reddish brown, hard, heavy, and strong.

131. *Calyptanthes sintenisii* Kiaersk. Hoja menuda, Limoncillo, Limoncillo de monte.

Tree from 15 to 25 feet high and from 6 to 10 inches in diameter, occurring in the Luquillo region. The wood is used in carpentry and for fuel and charcoal.

Wood fine and straight grained, hard, heavy, strong, and flexible. Pores small and numerous. Pith rays inconspicuous.

132. *Eugenia aeruginosa* P. DC. Guasávera, Guayabacón.

Tree from 30 to 60 feet high and from 1 foot to 2 feet in diameter, rather widely distributed on the island.

Wood light brown or chestnut colored, fine and straight grained, beautiful when polished, hard, heavy, strong, and flexible. Pores very small and arranged singly or in radial rows of from two to three between the very narrow inconspicuous pith rays.

NOTE.—Other species of this genus very similar to the above but of slight importance are *Eugenia stahlii* (Kiaersk.) Krug et Urb. (Guayabota, Limoncillo), tree from 15 to 60 feet high and from 1 to 2 feet in diameter; *Eugenia sintenisii* (Kiaersk.) Krug et Urb., from 45 to 60 feet high; and *Eugenia floribunda* West (Murta) 30 feet high. All are common throughout the island and their woods are similar to the preceding.

- *133. *Eugenia jambos* L. (= *Jambosa jambos* Millsp.). Poma rosa; Rose apple (Br. W. I.).

Tree from 20 to 50 feet high and from 1 to 2 feet in diameter, introduced from the East Indies and now largely naturalized throughout the island. The wood is used for barrel hoops, poles, fuel, and charcoal. It also furnishes material from which large baskets are made.

Wood grayish brown, fine and straight grained, hard, heavy, strong, and tough. Pores small and arranged in irregular tangential lines. Pith rays very narrow and scarcely visible under the hand lens.

XLIII. MELASTOMATACEÆ.

134. *Miconia tetrandra* (Sw.) D. Don. Camasey.

Tree from 30 to 50 feet high and about a foot in diameter, common in the mountains of Porto Rico and found on all the islands of the West Indies. The wood is used for poles, fuel, and charcoal.

Wood light brown, fine and straight grained, hard, moderately heavy, strong, flexible, and durable in the soil. Pores small, numerous, and evenly distributed. Pith rays very narrow and inconspicuous.

NOTE 1.—Three other species in this genus similar in size, distribution, and uses are *Miconia guianensis* (Aubl.) Cogn. (Camasey, Camasey blanco, Camasey de costilla); *Miconia impetiolearis* (Sw.) D. Don (Camasey, Camasey de costilla) and *Miconia prasina* (Sw.) P. DC. (Camasey).

NOTE 2.—Three other genera and six species in this family attain tree size, though they are of but slight local or general importance, namely, *Calycogonium squamulosum* Cogn. (Granadilla cimarrona), from 15 to 30 feet high, from the Sierra de Luquillo; *Calycogonium biflorum* Cogn., from 25 to 30 feet high, from near Barranquitas; *Heterotrichum cymosum* (Wendl.) Urb. (Camasey colorado, Camasey de paloma, Terciopelo), from 25 to 30 feet high, from various parts of the island; *Henriettella macfadyenii* (Triana), 60 feet high, from Sierra de Luquillo and Cordillera Central, found also in Jamaica; *Henriettella membranifolia* Cogn., 30 feet high, from Lares; and *Henriettella fascicularis* (Sw.) Ch. Wright (Camasey de oro, Camasey de paloma), from 25 to 30 feet high, from various places on the island, also throughout the Greater Antilles.

XLIV. ARALIACEÆ.

135. *Gilibertia arborea* (L.) E. March (= *Aralia arborea* L.). Muñeca, Palo cachumba, Pana, Vibona.

Tree from 30 to 60 feet high, quite common throughout the island, and found in all parts of the West Indies. The wood resembles boxwood (*Buxus sempervirens* L.) and should make a suitable substitute.

Wood light or pale yellow, very fine grained, taking a good polish, very hard, heavy, strong, and tough. Pores very small, numerous, scarcely visible under the hand lens, and evenly distributed. Pith rays very narrow and inconspicuous.

NOTE.—Another species in every way similar to the above is *Gilibertia laurifolia* E. March (Palo cachumba, Palo de gangulin, Palo de vaca, Vibona).

- *136. *Didymopanax morototoni* (Aubl.) Dcne et Pl. Yagrum macho, Yagrum; Grayume, Grayume macho, Grayumo, Pana cimarrona, Llagrumé, Llagrum macho.

Tree from 40 to 60 feet high and about a foot in diameter, very common in the mountains and distributed quite generally throughout tropical America. The wood is used for boards and beams in house building, and has been suggested as a good material for making matches.

Wood light olive brown, fine and straight grained, moderately hard, heavy, brittle, and not strong. Pores small, very numerous, and more or less evenly distributed throughout the annual rings of growth, which can be readily distinguished by means of the hand lens. Pith rays very conspicuous.

XLV. MYRSINACEÆ.

137. *Ardisia glauciflora* Urb. Mameyuelo.

Tree from 15 to 25 feet high, occurring in the Luquillo region. The wood is used for furniture.

Wood white, beautifully marked with fine lines, fine-grained, taking a good polish, hard, and heavy. Pores minute, isolated or in groups of two or three, evenly distributed. Pith rays numerous, broad, very conspicuous.

NOTE.—Another species, *Ardisia guadalupensis* Duchass. (Badula, Mameyuelo), attains a somewhat larger size and wider distribution on the island. Its wood is similarly used and has the same structural characteristics as the above but is a light reddish brown instead of white.

XLVI. SAPOTACEÆ.

*138. *Achras zapota* L. Sapodilla, Níspero¹; Naceberry, Bullet tree (Br. W. I.).

Tree from 30 to 45 feet high and about a foot in diameter. It is cultivated and wild on the island, having been originally introduced from Venezuela, and widely planted for the sake of its fruit. It is said to yield a gum similar to "gum chicle," principally obtained from *Mimusops globosa* and *Sapota zapotilla*. The wood is adapted for inside work, cabinetmaking, and furniture.

Wood light red with darker stripes, fine and straight grained, susceptible of a high polish, difficult to work on account of its extreme hardness, heavy (about 74 pounds per cubic foot), strong, tough, and very durable in contact with the soil. Pores very small, numerous, and arranged in more or less distinct radial rows between the narrow pith rays.

NOTE.—Closely related to the above is *Calocarpum mammosum* (L.) Pierre (Mamey Sapote; Bartaballi, [Br. Guiana]), a tree from 30 to 40 feet high and of limited occurrence on the island.

139. *Lucuma multiflora* A. DC. Acana, Hacána, Jácana; Contrevent (Br. W. I.).

Tree from 40 to 90 feet high and from 2 to 3 feet in diameter, found quite generally on the island and throughout tropical America. It yields very excellent timber which is used for mill rollers, frames, furniture, and house building.

Wood light colored, fine and straight grained, beautiful when polished, hard, very heavy, strong, tough, and durable. Pores small and arranged in radial rows. Pith rays narrow and indistinct.

140. *Micropholis*.

There are three tree species in this genus, *Micropholis garcinifolia* Pierre (Caimitillo), from 45 to 60 feet high; *Micropholis curvata* (Pierre) Urb. (Leche prieto), from 30 to 60 feet high; and *Micropholis chrysophylloides* Pierre (Caimitillo, Leche prieto), from 60 to 75 feet high, the former in the Sierra de Luquillo chiefly and the others in the Sierra de Cayey and Cordillera Central. The wood, particularly of the last named, is very hard and heavy, similar to that of *Achras Zapota* and is regarded locally as a first-class wood.

*141. *Sideroxylon fetidissimum* Jacq. (= *S. mastichodendron* Jacq.). Ausubo,² Tortuga, Tortugo amarillo, Tortugo prieto; Caguani (Cuba); Mastic (Fla.).

Tree from 30 to more than 50 feet high and from 2 to 3 feet in diameter, occurring on the coast. It is common in southern Florida and throughout tropical America

¹ This should not be confused with the true medlar, *Mespilus germanica* L., to which the Spanish "níspero" most commonly applies, nor with the Japanese medlar or loquat (*Eriobotrya japonica* Lindl.), neither of which are known to the Porto Rican public (C. & C.).

² Two species, *Sideroxylon fetidissimum* and *Mimusops nitida* are both known as "ausubo." Of the former Gifford and Barrett say, that it is "probably the most valuable wood per cubic foot in Porto Rico," although they admit that "possibly two species are included under this name," which is more likely. According to Urban, *Sideroxylon fetidissimum* is not reported from the Sierra de Luquillo or other parts of the interior, while *Mimusops nitida* is. According to Fernow and Taylor, however, this *Sideroxylon* is widely distributed in the Sierra Maestra (Cuba).

and the West Indies, ranking as a very valuable timber. The wood is used locally for all purposes requiring great strength and durability, such as beams and rafters, also for all parts of wheels, axles and other parts of native bull carts, for ox yokes and other native uses, and somewhat for furniture.

Wood maroon-red, very fine and straight grained, susceptible of a good polish, easily worked considering its hardness, and very durable in the Tropics; in the temperate climate it is less durable. Wood hard, heavy (about 65 pounds per cubic foot), strong, and tough. Moderately conspicuous ducts in short detached long and short chains (single lines of cells) evenly diffused; chains usually between two medullary rays. Medullary rays very numerous, minute, indistinct. Wood fibers slightly interlaced and appearing straight-grained. Resembles somewhat a fine-grained teak. (Hill and Sudworth.)

NOTE.—Another species of very limited distribution is *Sideroxylon portoricense* Urb. (Tabloncillo), a tree from 75 to 90 feet high, reported only from the vicinity of Utuado and Lares. Wood similar to that of *Sideroxylon fatidissimum*, and probably similarly used.

***142. *Dipholis salicifolia* (L.) A. DC.** Almendrón, Tabloncillo.

Tree from 30 to 40 feet high and from 12 to 18 inches in diameter, occurring in dry limestone soils near the coast. It is common in southern Florida and throughout the West Indies. The wood is used locally principally for fuel and charcoal.

Wood dark brown-red, fine and straight grained, taking a beautiful polish, hard, heavy (about 55 pounds per cubic foot), strong, and tough.

NOTE.—Another rather incidental species is *Dipholis sintenisiana* Pierre (Espejuelo), a tree from 60 to 70 feet high, from the northwestern part of the island, having a wood similar to that of *D. salicifolia*.

***143. *Chrysophyllum cainito* L.** Cainito, Caimito, Caimito morado; Star apple (Br. W. I.).

Tree from 45 to 60 feet high and from 12 to 18 inches in diameter. It is a cultivated and wild tree and found in most parts of the island. The wood is suited to a variety of uses and particularly in exposed situations.

Wood red or reddish-brown, very fine and curly grained, taking an excellent polish, hard, heavy, strong, tough, and very durable in contact with the soil. Pores very small and arranged in short radial rows between the rather inconspicuous pith rays.

***144. *Chrysophyllum oliviforme* L.** Teta de burra, Lechesillo.

Tree from 30 to 40 feet high and about a foot in diameter from the southwestern part of the island. It is distributed throughout the West Indies and southern Florida, but is nowhere common.

Wood light brown tinged with red, fine and straight grained, taking a good polish hard, heavy (about 58 pounds per cubic foot), very strong, and tough. Pores small and arranged in short radial rows, which are easily seen on a smooth transverse surface under a hand lens.

NOTE.—Other species of this genus are *Chrysophyllum bicolor* Poir. (Caimitillo, Lechesillo), from 30 to 50 feet high, occurring very locally and in Porto Rico only; *Chrysophyllum argenteum* Jacq. (Caimito verde, Lechesillo), from 25 to 60 feet high, occurring rather widely distributed throughout the island and others of the West Indies, and *Chrysophyllum pauciflorum* Lam. (Caimito de perro), from 40 to 60 feet high, reported only from the southern part of the island. Wood of each is similar to that of the above.

145. *Mimusops*.

Two species of this genus occur in Porto Rico, *Mimusops nitida* (Sessé et Moc.) Urb. (Acana, Ausubo¹), a tree from 20 to 50 feet or more high, occurring in mountainous regions; and *Mimusops duplicata* (Sessé et Moc.) Urb. (= *M. globosa* Griseb.) (Mameyuelo, Sapote, Sapote de costa, Zipote, Balata), from 40 to 60 feet high, occurring along the north coast. Both are local species.

¹ See footnote under *Sideroxylon fatidissimum*.

Wood of these two species is dark brown, fine and straight grained, taking a splendid polish, hard, heavy (about 60 pounds per cubic foot), strong, tough, and very durable in contact with soil and water. Pores very small, and arranged in more or less oblique radial rows which are visible under the hand lens.

XLVII. EBENACEÆ.

146. *Maba sintenisii* Krug. et Urb. Guayabota-nispero, Tabeiba.

Tree from 25 to 30 feet high, of uncommon occurrence, reported from only two localities on the island.

Wood very light brown, very fine and straight grained, taking a very good polish, very hard, heavy, strong, tough, and durable. Pores very minute, numerous, and arranged in indistinct radial rows. Very fine tangential lines of soft tissue are visible under a strong hand lens.

***147.** *Diospyros ebenaster* Retz. Guayabota; Zapote negro ó prieto (Mexico).

Tree about 30 feet high, of infrequent occurrence in the mountains. It is native of the West Indies, Mexico, and Malay Islands. It has a black bark and heartwood. This tree attains much larger size in Mexico than it does in Porto Rico, where it is used only for fuel and charcoal.

XLVIII. SYMPLOCACEÆ.

148. *Symplocos*.

Genus represented in Porto Rico by five tree species, namely, *Symplocos lanata* Krug et Urb. (Palo de nispero cimarron), from 24 to 30 feet high, from Adjuntas and Peñuelas; *Symplocos micrantha* Krug et Urb. (Palo de cabra), from 20 to 50 feet high, from the Sierra de Luquillo and Cordillera Central; *Symplocos martinicensis* Jacq. (Aceituna, Aceituna blanca, Aceituna cimarrona), from 10 to 30 feet high, from Bayamon and Añasco; *Symplocos polyantha* Krug et Urb. (Palo de cabra), from the Sierra de Luquillo; and *Symplocos latifolia* Krug et Urb. (Aceituna), from 25 to 45 feet high, from Sierra de Cayey and Cordillera Central. Except for the third of these, which occurs generally throughout the West Indies, all are local species. Their woods, which are alike, are apparently very little used.

The wood of *S. martinicensis* is white, hard, moderately heavy, and strong. Pores small, numerous, isolated or in groups of two to four, evenly distributed. Pith rays narrow, inconspicuous.

XLIX. STYRACACEÆ.

149. *Styrax portoricensis* Krug and Urb.

Tree apparently little known even locally. Reported as being from 30 to 60 feet high and occurring only in the mountain forests of the eastern part of the island.

L. OLEACEÆ.

150. *Linociera domingensis* (Lam.) Knobl. (= *Mayepea domingensis* Krug and Urb.). Hueso blanco, Palo de hueso, Huesillo, Palo blanco.

Tree from 30 to 45 feet high, quite generally distributed throughout the northern part of the island. Common also to the other islands of the Greater Antilles.

Wood light colored, moderately fine grained, hard, and moderately heavy. Pores small, isolated or in groups of from two or three, evenly distributed. Pith rays narrow, inconspicuous.

LI. APOCYNACEÆ.

151. *Plumiera alba* L. Alelí, Alelí cimarron, Tabeiba; Frangipanic blanc, Bois de lait (Fr. W. I.).

Tree from 20 to 30 feet high and from 6 to 10 inches in diameter, occurring along the coast, very common throughout tropical America. The wood is used for carpentry work, and as a substitute for true sandalwood (*Santalum album* L.).

Wood yellowish-white or light grayish-yellow, marked with numerous irregular undulating lines, giving the wood a very pleasing appearance. It is very compact and fine grained, taking a very good polish, hard, heavy, strong, and tough.

152. *Rauwolfia nitida* Jacq. Cachimbo, Palo amargo, Palo de muñeco.

Tree from 30 to 60 feet high, common to the sandy coast soils. Common also to other of the West Indies.

LII. BORRAGINACEÆ.

153. *Cordia alliodora* (R. & P.) Cham. (= *C. gerascanthus* Jacq. and *C. gerascanthoides* C. & C.) Capá, Capá prieta; Prince wood, Spanish elm (Jamaica).

Tree from 30 to 60 feet high and from 12 to 18 inches in diameter, found commonly in the mountainous interior. Although now rather scarce, this wood is very highly prized locally because of a variety of good qualities. In Jamaica it is considered one of their best woods. It is used for furniture, flooring, doors, venetian blinds, beds, interior finish, carriage building, posts, and cooperage.

Wood rich light brown with dark streaks, fine grained, taking a good polish, moderately hard and heavy (about 36 pounds per cubic foot), strong and durable. Pores small, numerous, isolated or in groups of from two or three, evenly distributed. Annual rings of growth visible on a smooth transverse surface. Pith rays narrow but conspicuous, visible to the unaided eye on a smooth transverse surface.

NOTE.—Other species of this genus are *Cordia sebestena* L. (Vomitel colorado, San Bartolomé; Aloe wood [Br. W. I.]; Geiger tree [Florida Keys]), from 20 to 35 feet high, occurring along the eastern, southern, and western coasts. It is often planted as an ornamental tree in tropical gardens. Wood brown, fine grained, moderately hard, and heavy. *Cordia collococca* L. (Cereza cimarrona, Palo de muñeca; Clammy cherry [Jamaica]), from 15 to 30 feet high, occurring in the southwestern part of the island near the coast. Used for barrel staves in Jamaica, having a wood which is soft, brittle, and not durable. *Cordia nitida* Vahl. (Cerezas, Cereza cimarrona, Muñeca), from 15 to 60 feet high, occurring in the southern part of the island. *Cordia sulcata* DC. (Moral, Moral de paz), from 30 to 60 feet high, found in the interior mountain forests. Wood little used. **Cordia borinquensis* Urb. (Muñeca, Palo de muñeca, Capá cimarron), from 20 to 60 feet high, found in interior mountain forests, having wood light yellow, fine grained, taking a good polish, moderately heavy, and hard.

LIII. VERBENACEÆ.

154. *Citharexylum fruticosum* L. (= *Citharexylum quadrangulare* Griseb.). Péndola; Péndula, Pendula colorado, Palo de guitarra, Balsamo, Higuerrillo.

Tree from 20 to 40 feet high and from 12 to 20 inches in diameter, occurring near the eastern and southern coasts. It is used for furniture and in house building. The natives make their guitars from it.

Wood light red, moderately fine-grained, fairly hard, heavy (about 46 pounds per cubic foot), and strong.

NOTE.—Incidental species in this and a closely allied genera are *Citharexylum caudatum* L. (Higuerrillo), from 15 to 60 feet high, from the Sierra de Luquillo and Cordillera Central, also occurs in the other of the Greater Antilles, the Bahamas, and Mexico; and *Callicarpa ampla* Schauer (Capá rosa, Péndola cimarron), from 25 to 50 feet high, occurring only in mountainous regions of Porto Rico.

***155. *Petitia domingensis* Jacq.** Capá, Capá blanca, Capá sabanero, Capá de sabána, Capá amarillo, Palo de capá de sabána; Fiddle wood (Br. W. I.).

Tree from 20 to 50 feet high and 2 feet or more in diameter, occurring chiefly in the interior. Common also to the other islands of the Greater Antilles. The wood is used locally for making rollers in coffee-hulling mills and is suitable for cabinetwork, interior finish, and general building purposes where a hard, tough wood is required.

Wood light to dark brown, streaked with a decidedly beautiful wavy grain, moderately fine grained, taking a good polish, hard, and heavy. Pores small, isolated, or in groups of two or three, evenly distributed. Pith rays minute, inconspicuous. Structurally similar on the radial section to the American beech.

- 156.** *Vitex divaricata* Sw. Higuerillo, Péndula, Palo de péndula, Péndula blanco; Lizard wood, Fiddle wood (Br. W. I.).

Tree from 30 to 60 feet high and from 20 to 30 inches in diameter, found in mountainous regions, common to many of the islands of the Lesser Antilles. Used locally for shelves, boards, framework of houses, in cabinetwork, and suitable for all inside and outside work.

Wood white, moderately fine grained, hard, heavy (about 50 pounds per cubic foot), strong, and durable. Pores small, isolated or in groups of from two to five. Pith rays narrow, inconspicuous.

- *157.** *Avicennia nitida* Jacq. Chifle de vaca, Mangle blanco, Mangle bobo; Black mangrove (Br. W. I.).

Shrub or tree from 40 to 70 feet high and from 12 to 24 inches in diameter, found in tidal swamps. Widely distributed throughout the West Indies, and the shores of the American and African continental Tropics. The wood is used locally for foundations, underpinning for houses, fence posts, drains, and for charcoal and fuel.

Wood dark brown, rather coarse grained, with conspicuous tangential lines visible on a transverse surface, hard, heavy, and very durable in damp situations. Pores small, isolated or in groups of from two to five, arranged largely in radial lines. Pith rays narrow, inconspicuous.

LIV. BIGNONIACEÆ.

158. *Tabebuia*.

This genus embraces two local species, first described by Urban in 1899, of very limited distribution, namely, *Tabebuia rigida* Urb. (Roble), from 20 to 60 feet high from the Luquillo region, and *Tabebuia schumanniana* Urb. (Roble colorado), from 30 to 50 feet high, occurring in the mountains near Utuado.

Wood light brown, fine grained, taking a good polish, moderately hard and heavy, strong, tough, and very durable. Pores small, numerous, arranged in conspicuous tangential lines visible to the unaided eye on a smooth transverse surface. Pith rays inconspicuous.

- *159.** *Tecoma pentaphylla* (L.) Juss. Roble, Roble blanco; West Indian boxwood.

Tree from 20 to 60 feet high, quite common throughout the island, particularly in the limestone hills, and found in the Antilles generally. The wood is used in Porto Rico and throughout tropical America for ox yokes, piles, for house and boat building, and for general purposes.

Wood white and fine grained, moderately hard, heavy (about 52 pounds per cubic foot), and strong. Pores small, isolated or in groups of two or three, evenly distributed. Faint tangential lines of soft tissue may be seen with a hand lens. Pith rays minute, inconspicuous.

- 160.** *Tecoma lewycoxylon* (L.) Mart. Roble, Roble prieto; White wood (Br. W. I.).

Tree from 20 to 60 feet high most commonly found in the limestone hills of the south coast and less frequently in the Sierra de Luquillo and Cordillera Central. Not an important tree in Porto Rico, but in other parts of tropical America it yields a wood used for furniture, house building and sounding boards, and musical instruments, also for posts, piles, and other purposes in exposed situations.

Wood resembles somewhat that of the preceding.

NOTE.—Another species of little importance is *Tecoma haemantha* (Bertero) Griseb. (Roble), from 25 to 30 feet high, from the coast hills and interior valleys.

- *161.** *Crescentia cujete* L. Higüero; Calabash (Br. W. I.); Jícara, Tigulate, Temante, Palo de melon, Melon tree (Mexico and Central America).

Wild and cultivated tree from 10 to 45 feet high and from 12 to 18 inches in diameter, widely distributed throughout the island. The wood is not known to be used locally, but the rind or bony outside covering of the fruit, like the shell of the coconut, finds a multiplicity of domestic uses for cooking utensils and tableware. The wood is used

in Jamaica for tool handles, carriage parts, fellies of wheels, saddles, and chairs. It is also employed for ship's knees and cabinetwork in Mexico and Central America.

Wood light brown, coarse grained, taking a good polish, moderately hard, heavy (about 54 pounds per cubic foot), very tough, flexible, and durable in the ground. Pores small, isolated or in groups of two or three, evenly distributed. Alternating tangential wavy lines of hard and soft tissue are barely visible to the unaided eye on a smoothly cut tranverse surface. Pith rays narrow, inconspicuous.

LV. RUBIACEÆ.

162. *Rondeletia portoricensis* Krug & Urb.

A recently described tree from 20 to 60 feet high and from 12 to 20 inches in diameter, occurring in various places in the Sierra de Luquillo and Cordillera Central.

*163. *Randia aculeata* L. Tintillo, Palo de espinillo, Palo de cotorra, Cambrón, Escambrón; Ink berry (Br. W. I.).

Tree from 20 to 30 feet high and from 6 to 9 inches in diameter, widely distributed throughout the island. Wood little used.

Wood dark brown, fine, close and straight grained, taking a very good polish, hard, heavy, strong, tough, and very durable. It resembles the true lignum-vitæ in general appearance. Pores exceedingly small and indistinct. Pith rays very narrow and scarcely visible under the hand lens.

*164. *Genipa americana* L. Jagua, Hagua.

Tree from 30 to 60 feet high and from 15 to 20 inches in diameter, widely distributed throughout the island and the West Indies generally. The wood is suitable for packing boxes, shoe lasts, barrel hoops, and wherever strength and elasticity are required.

Wood light brown, tinged with red, very fine grained, moderately hard, heavy (about 54 pounds per cubic foot), strong, tough, and durable; in these qualities it resembles the ash. Pores small, isolated, or occasionally in pairs, evenly distributed. Pith rays numerous, narrow, inconspicuous.

165. *Guettarda scabra* (L.) Lam. Palo de cucubano, Serrasuela.

Tree from 20 to 40 feet high and from 8 to 12 inches in diameter, occurring in the coast hills chiefly, and sparingly in the interior valleys. The wood is used principally in building native huts.

Wood ash-colored, moderately fine grained, rather hard and heavy (about 54 pounds per cubic foot). Pores small, isolated or in groups of from two to five or more, and evenly distributed. Pith rays small, inconspicuous.

NOTE.—Other less important species with very limited distribution and wood similar to the above are *G. krugii* Urb., *G. ovalifolia* Urb., and *G. lævis* Urb., which attain a height of from 30 to 60 feet and occur chiefly in the coast hills and shore woodlands.

166. *Antirrhæa obtusifolia* Urb. Tortuguillo.

Tree from 25 to 45 feet high, found in the mountains of the Luquillo region and Yabucoa. The wood is apparently little used, although suitable for structural and cabinet work.

Wood light reddish-brown, straight and fine grained, taking a good polish, hard, heavy, and strong. Pores minute, evenly distributed throughout the annual rings of growth, which are easily visible to the unaided eye.

167. *Antirrhæa coriacea* (Vahl.) Urb. Quina, Palo de quina, Boje, Boje quina.

Tree from 40 to 50 feet high and sometimes 2 feet in diameter, chiefly occurring in the northern part of the island. Occurs also in several of the islands of the Lesser Antilles. The wood is used for carpentry work, furniture, cabinetwork, and framework of houses.

Wood yellowish, very fine and straight grained, taking a very good polish, hard, heavy, strong, though brittle, and very durable in contact with the soil.

NOTE 1.—*Antirrhæa sintenisii* Urb. (Quina) is a tree sometimes 45 feet high, described from the limestone hills in the vicinity of Utuado, Lares, and Manati, and yielding yellowish wood similar to that of *Antirrhæa coriacea*.

NOTE 2.—*Chione*, a closely related genus, is represented by one species of little known importance. *Chione venosa* (Sw.) Urb. (Martin avila, Palo blanco, Santa olalla), a tree from 20 to 50 feet high reported from the Sierra de Luquillo, Sierra de Lares, and the vicinity of Bayamon and Toa-Alta. Found also in several other of the West Indies. Wood is said to be made into lumber.

*168. *Coffea arabica* L. Café, Café macho; Coffee (Br. W. I.).

A cultivated and seminaturalized tree from 10 to 20 feet high and from 2 to 4 inches in diameter, grown in plantations at all elevations but doing best in sheltered locations at or above 2,500 feet on the northern and western parts of the island. Native of Arabia. Coffee is one of the most important articles of export of Porto Rico. The wood is often used for walking sticks.

Wood white, very fine grained, taking a fine polish, hard, heavy, strong, and tough. Pores minute, very numerous and evenly distributed. Pith rays minute and inconspicuous.

*169. *Ixora ferrea* (Jacq.) Benth. Palo de hierro, Dajao, Palo de dajao, Hackia; West Indian or Martinique ironwood (Br. W. I.).

Tree from 15 to 30 feet high, occurring quite generally in the limestone hills and somewhat on the slopes of the interior mountains. Elsewhere in the West Indies and in the northern part of South America it sometimes attains a height of from 30 to 60 feet and a diameter of from 1 foot to 2 feet. The wood is not reported as being used locally, but in the other countries where it occurs it is used largely for cogs, shafts, and furniture.

Wood dark brown, taking a very beautiful polish, exceedingly hard, heavy, very strong, and tough.

170. Other genera of this family represented by tree species.

Psychotria brachiata Sw. (Palo de cichimbo), usually a shrub or small tree, but occasionally 45 feet high; *Palicourea alpina* (Sw.) DC., shrub or small tree from 15 to 30 feet high; and *Faramea occidentalis* (L.) A. Rich (Cafeillo, Palo de toro), from 15 to 45 feet high, all rather widely distributed locally as well as generally throughout the West Indies.

LVI. CAPRIFOLIACEÆ.

171. *Sambucus intermedia* var. *insularis* Schwerin. Saúco.

A cultivated and seminaturalized tree occurring in various places throughout the island. Introduced from Central America and found in many of the other West Indian Islands.

LVII. GRAMINEÆ.

172. *Bambusa vulgaris* Schrad. Bambú; Bamboo.

This bamboo (although the bamboos belong to the grass family and are not trees at all) has an erect wood stem which attains a height of 40 feet and a diameter of 4 inches, and is rather commonly distributed over the island, particularly along the watercourses and throughout the West Indies. It is a native of Java. The bamboos, of which there are many species, are adapted to a wide variety of uses and their planting should be greatly extended in Porto Rico.

APPENDIX II.

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EXTENSION COURSE IN SOILS.

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GENERAL SUGGESTIONS TO LEADERS.

Although it is not necessary that the leader of this course shall have had any special training, his work will be easier if he reads at least a lesson ahead of the class work, or, better still, goes more or less rapidly through the whole bulletin in advance. In this way it will be easier for him to make suggestions regarding the practice work in connection with each lesson.

The references of each lesson have been carefully selected and are thought to be about sufficient to utilize the remainder of the forenoon after the lesson text has been carefully read and discussed. Where a choice is given between two references, the leader may use his judg-

NOTE.—This course has been prepared by direct cooperation between the authors and J. M. Stedman, Farmers' Institute Specialist, of the States Relations Service, and is designed to aid agricultural colleges in their extension work. It is intended for the use of small groups of farmers assembled as a class to study the subject in a systematic manner with one of their number as a leader. It is adapted for use in any part of the United States. The agricultural college is to loan the class the reference library listed in the Appendix and also a set of apparatus and the supplies designated therein. The class meets as often as convenient in a suitable room where tables for exercise work are available. The forenoon is devoted to the lesson and reference work and the afternoon to the exercise work, an entire day being thus consumed for each lesson. At the completion of the course and as often as desired the college conducts examinations through the leader and corrects and returns the papers.

ment as to which will be most profitable for the class to read. No attempt should be made to read tables of record data, but many of these can be carefully studied by the class and conclusions called for by the leader. If in any lesson the references should be too short, it will be easy to select others from the reference library; if, on the other hand, they should prove to be too long, the leader can cause certain parts of least importance to be omitted.

The exercise equipment and supplies should be put away, and only such parts of them as are needed for the exercise in hand should be handled or used during the period. The leader should make himself responsible for this practice by the class.

The queries at the end of each exercise are intended to aid in fixing the leading points of the lesson in the minds of the members and should be conducted at the close of the practicum work. The majority of the questions have to do with facts brought out in the lessons, but some of them refer to matters which the class is expected to have gathered from experience and thought.

LESSON I. ORIGIN, FORMATION, AND COMPOSITION OF SOILS.

The intelligent use and management of the soil is based on an understanding of its structure and composition. A good soil consists largely of two parts: (1) The *organic* matter derived mainly from plants which have previously grown on the land and have decomposed more or less, but also to some extent from the remains of animal life; (2) *inorganic* or mineral matter, derived originally from rocks. If soil is burned at a red heat, the organic matter is burned off, leaving the rock material. The organic part is the principal factor contributing to the dark color of soils. The inorganic is that derived from the rock and is made up of particles of all sizes from coarse sand or gravel down to those so minute that they can not be seen by the naked eye. Both the organic and the inorganic matter play important parts in determining soil fertility.

ORIGIN OF SOIL.

Rocks and minerals as soil factors (Ref. No. 3, pp. 1-3, 7-12).—Minerals are the substances of which rocks are composed and constitute the inorganic part of soils. Some familiar minerals are gypsum or land plaster, and calcite, which occurs in marble and limestone. Some of the most common rock-forming minerals are quartz, feldspar, hornblende, and mica. White sand is nearly pure quartz. The fertility of the soil is closely related to the minerals which it contains.

Rocks are masses of minerals, physically united, and form a considerable portion of the earth's crust. Geologically rocks are grouped with regard to their origin and structure. The most important group, agriculturally, are the aqueous rocks, so-called because they

are believed to have been formed mainly through the agency of water. Examples of one class of these rocks are the deposits of gypsum and phosphate beds. The most important classes of the aqueous rocks, however, are those of sedimentary origin. They are composed of the materials resulting from disintegration of older rocks and from the mineral remains of animal and plant life. These rocks are largely distributed over the earth's surface and include the limestones, the sandstones, and the shales.

Organic matter as a soil factor (Ref. No. 7, pp. 120-125).—The organic matter of the soil has many important relations to the soil's fertility. Vegetable matter, commonly in the form of leaves, and of stems and roots of plants which have died, undergoes a process of decomposition in which it breaks down into simpler substances. When moisture and the air have ready access to it, vegetable matter slowly decomposes into the substances which were taken by the plant, in growth, from the soil and those which were absorbed from the atmosphere. The process is much the same as though the vegetable matter were slowly burned, and, like burning, it produces volatile gases and mineral ash, which again serve as plant-food materials. However, when the air does not have ready access to the decomposing vegetable matter, it undergoes much slower and often different changes, yielding residues known as humus, muck, and peat.

Humus may be defined for present purposes as vegetable matter in such an advanced stage of decomposition as to have lost its original physical identity. The degree of fertility of soils is very closely related to the amount of humus which they contain, and one of the most important problems of a farmer is to manage his soil so as to retain a high humus content. The quantity of vegetation returned, the drainage, the temperature, and the character of the soil are conditions affecting humus content. Peat and muck are terms applied to vegetable matter which has undergone changes under water, largely without air, and which may be in various stages of decomposition. Marsh soils are largely composed of muck and peat.

FORMATION AND COMPOSITION OF SOILS.

Agencies of soil formations.—The principal agencies which have formed soils from rocks and organic matter may be classified as physical, chemical, and biological. (Ref. No. 9, pp. 1-6.)

A physical change in matter is one which does not produce a substance or substances of different composition. For example, the changes of water to ice or to steam are physical. The form of the matter is changed, but not the composition. Likewise, the dissolving of salt in water produces a physical change. The physical

agencies which have most affected the formation of soils are temperature changes, or heat and cold, water, ice, and wind.

A chemical change, or reaction, is one which separates or rearranges the elements of a substance or compound. Chemically, an element is a single substance which can not be separated into two or more different substances; a compound is a union of two or more elements in certain definite proportions. Gold, silver, quicksilver, oxygen, and nitrogen are examples of elements. There are about 80 known elements. Common salt is a compound of the elements sodium and chlorine; water is a compound of the elements hydrogen and oxygen; carbon dioxide, present in the air, is a compound of the elements carbon and oxygen. The formation of carbon dioxide in the decomposition of vegetable matter and the uniting of this gas with other substances to form carbonate compounds, are common examples of chemical changes in the soil.

A biological change is one resulting from plant or animal life within the soil and may affect soil substance physically or chemically. Insect life in the soil is a matter of common knowledge. When plant or animal organisms are so small that they can be identified and studied only by the use of the microscope, they are called microorganisms, and a study of those commonly occurring in the soil is called soil microbiology or soil bacteriology. Nitrification, or formation of nitrates, is a typical example of microbiological (bacterial) changes in soils. The work of nodule-forming bacteria upon the roots of red clover, alfalfa, and other leguminous plants, is another example of such changes affecting the productiveness of soils. The biological changes produced in the soil are very extensive and important. See Lesson VI.

The physical, chemical, and biological factors which have been potent agencies in the formation of soil for past ages are constantly producing soil changes. Their action may be advantageously controlled to some extent by the farmer, as will be shown in other lessons.

Residual soils (Ref. No. 3, pp. 31-35).—Soils formed from the rocks immediately underlying them are called residual soils. On examining a stone quarry, it is usually found that the upper portion of the quarry rock is more or less broken up and pieces of the rock are embedded in the lower layer of the soil. In fact, the finer pebbles and cobbles of stone often extend all the way to the surface of the soil. A careful study will show that the soil itself has really been formed from the rock. This has resulted from the action of several agencies. Among them the expansion and contraction of the rock due to alternate heating and cooling are very important. The expansion of water as it freezes has much the same effect. During the long period of transition from solid rock to thoroughly disintegrated rock,

or soil, the percentage composition of materials may be somewhat changed by the difference in solubility of the compounds forming the rock, and by other factors. Because of the wide variation of rocks forming residual soils and the changes which may take place during rock disintegration, these soils are of many kinds.

Granite rocks consist principally of the minerals feldspar, quartz, hornblende, and mica. In the decomposition of granites carbon dioxid, usually called carbonic acid, dissolved in soil water, combines with the elements potassium, sodium, or calcium in the feldspar, forming soluble carbonate compounds of these elements, while insoluble alumina and silica, uniting with small quantities of water, collect as clay. Quartz grains, on the other hand, are not appreciably affected by carbon dioxid, and so collect as sand in the soil. In this way there is formed from granites a mixture of clay, sand, and partly decomposed particles of all the minerals found in the granite rocks.

Soil is also formed from limestone rocks by weathering and solution. Limestone consists principally of calcium and magnesium carbonates. These slightly soluble carbonates are made more soluble through the action of carbonic acid in the water of the soil. A good illustration of such solution is the so-called hard water from a limestone well. When such water is boiled the carbon dioxid holding the calcium carbonate in solution is driven off and the carbonate is precipitated as a solid residue which often adheres to the containing vessel, forming what is known as scale. In soil formation from limestones, as the carbonates are dissolved and leach out, the impurities in the limestone, chiefly fine clay and silt, are left to collect and form a soil. Mixed with this fine residual clay and silt is usually found a great deal of stony material consisting largely of silica, and known as flint or chert. Soils formed from limestones are, therefore, largely clay, containing more or less flint or chert.

In the formation of soils from sandstone rocks the changes taking place are largely physical, and the composition of the soils differs but little from that of the rocks from which they are derived. The chief process is the disintegration of the rock and the separation of the sand grains through freezing and thawing and the action of water. Soils formed in this way from sandstones are, of course, sandy in character, though they may be somewhat finer than the rock itself, since the grains of sandstone not only separate one from another, but split up into somewhat finer parts.

The principal area of residual soil in the United States is south of a line extending roughly from New York to Pittsburgh, thence following the Ohio River to the Mississippi River, up the Mississippi and Missouri Rivers to the Dakotas, and from thence west to the Puget Sound region in Washington, where it turns well southward. From this area, however, should be excluded the coastal plains,

deposits which, in the South Atlantic and the Gulf Coast regions, have an average width of over 100 miles and which are not residual soils, but there should be added numerous small areas of residual soils scattered throughout areas of other kinds of soil.

Cumulose or swamp soils (Ref. No. 3, pp. 35-38).—This type of soil is related to residual soils in that it has been formed largely from materials not transported. When plants grow where water fills the soil most of the time, the lack of air in the land surface hinders the decay of organic matter to the extent that large deposits of this material finally collect. Such accumulations going on for ages result in what are commonly known as peat bogs or muck swamps. They contain, as a rule, only such mineral matter as has been washed in from adjoining areas. Cumulose soils are widely distributed and vary greatly in area. In this country they are most numerous in the northern United States, while larger areas of slightly different type, known as seacoast swamps, are common along the Atlantic and Gulf coasts. Such soils are generally useless for agricultural purposes until drained. The management of marsh soils, however, is considered in Lesson X.

While soil in many cases has been derived as above explained from the rock directly under, or from plant remains in place, there are many kinds of soil which were formed in other sections of the country and have been brought to their present location by some natural agency. The three most important agencies transporting soil materials are water, ice, and wind.

Alluvial soils (Ref. No. 2, pp. 43-50).—The action of water as a soil-forming agent is a matter of common observation. Whenever streams flood and overflow their banks they deposit some of the sediment brought down from higher up in their valleys. In this way they frequently form layers of sand or fine gravel when the stream is rapid, and of silt when it is moving very slowly, and in the broad, lakelike floods which occupy the larger valleys of the more important rivers the finest sediment, or clay, is frequently deposited in deep layers. Soils thus transported by water are called alluvial soils. They are always stratified, and the strata frequently vary a great deal in the size of grains, so that a layer of gravel is often found under one of coarse sand, and a layer of coarse sand under one or more of fine silt. For this reason alluvial soils differ greatly in character, and one must examine the subsoil of any alluvial field if he desires to know its condition and value. Alluvial soils include large agricultural areas, and when well drained are among the most productive soils of the earth's surface. The high percentage of organic matter which they commonly contain and the frequent renewing of fertility by repeated overflows (in case of the low-lying alluvial soils) are reasons why they keep productive. The Nile Valley in Egypt is a

notable example of alluvial deposit regularly renewed. Large soil areas of this nature are common in the valleys of the Mississippi River and its tributaries, and those of smaller extent are common in the northern United States.

Glacial soils (Ref. No. 2, pp. 54-61).—In lands far toward the poles snow accumulates to great depths, and its pressure becomes such as to compact it into immense fields of ice. Where sloping land surfaces or valleys occur, the force due to gravity causes these sheets of ice, called glaciers, to move slowly down the inclines, grinding the rock surfaces and carrying along large boulders and much soil material. When the ice front of winter begins to melt and recede, as summer approaches, there is left a layer of miscellaneous ground rock materials whose position has been more or less affected by the carrying properties of the water formed by the melting ice. Such formations of soil are constantly being produced in the Arctic and Antarctic regions. This condition illustrates a period in recent geological times when immense sheets of ice moved over the land surface of the earth, in both Northern and Southern Hemispheres, much beyond the present limits of perpetual snow. Soils formed as the result of the action of glaciers during this ice age are called glacial soils. (Ref. 3, p. 52.) In the United States soils of glacial formation extend approximately to the line described as the northern boundary of residual soils, page 5.

It is easy to understand how the character of glacial soils may vary widely even within the limits of small areas, since they are composites of all the rock materials over which the ice sheets have passed. Where the ice moved across granite rocks it mixed the residual soil previously formed from the granite with cobbles and boulders brought from farther north. The granite rock itself was too hard to be much affected by the ice, though it was often polished quite smooth. On the other hand, when the ice sheets passed over areas underlain by sandstone, which is much softer than granite, the rock was ground up and formed into a sandy soil of rolling topography. The chemical composition of the soil, however, like residual soils from the sandstone, was not much changed. The ice in passing over limestone country ground up a good deal of the limestone underlying the surface residual soil, mixing it with the surface and forming a soil richer in limestone, or calcium carbonate, than the corresponding residual soil. The glaciers in their movement often filled up valleys and in many cases left shallow basins which filled up with water until an outlet was found. The region which was covered by glacial ice is characterized, therefore, by a large number of small lakes and marshes since formed in lake beds. When the glacial sheets receded, the water flowing from the melting ice carried with it the sedimentary materials ground up in the ice, producing fanlike plains

and frequently filling valleys beyond the ice border with gravel, sand, and finer sediment to a depth of from 50 to 200 feet.

Glacial soils, as would be supposed, vary widely in their productive capacity, and the management of soils within the glacial area is often difficult because of the wide differences in soil types which may occur even within the boundaries of a single farm.

Wind-formed soils—*Loess* (Ref. Nos. 2, pp. 68–69; 3, pp. 59–61).—It is a familiar fact that the atmosphere carries suspended a considerable quantity of fine dust particles and that after rains and snows the air is left clearer because much of the dust has been carried to the earth by the falling raindrops or snowflakes. During high winds, when the land surface is dry and not covered by vegetation, the air frequently becomes so laden with fine soil that one can see for only a short distance. Where windbreaks occur these soil grains are often deposited in large quantities, forming soil drifts of varying character. The sand dunes bordering the shores of the Great Lakes are of wind formation. On the Great Plains of the western United States, where the soil is dry and heavy winds are common, considerable damage is often done to farms by the transportation and drift of soil from place to place.

Loess is a type of soil of a fine, silty composition, which commonly contains a considerable amount of calcareous materials. Loess has a peculiar ability to stand in nearly vertical walls when eroded by wind or stream. Such soils are unusually uniform, both in physical and mineral composition, and possess high natural fertility. An extensive area of typical loess soil is found in the Chinese Empire, where the material, as above described, extends to the depth of 1,000 feet or more. This immense deposit is generally believed to have been transported by the wind. The so-called loess soil of the United States, however, extending over much of the Mississippi Valley, is commonly believed to have been transported largely by water. Its depth varies from a few feet in the outer edges of the area to 150 feet, or more, in the more central portions.

EXERCISES, LESSON I.

Materials needed.—Samples of typical soils found in the community, including marsh soil, if any; hand lens; long pickle bottles with corks; a few pieces of rock candy (this can be secured at the local store); specimens of common rock, such as granite, trap rock, schist, shale, slate, limestone, marble, sandstone, and quartzite; specimens of common rock-forming minerals—feldspar, hornblende, quartz, black and white mica, calcite, and gypsum.

ROCKS AND MINERALS.

(a) Examine carefully the rock-forming minerals—feldspar, quartz, hornblende, mica, and calcite. Compare relatively their weight, then note color and plane or direction of cleavage of each, after which determine their relative degree of hardness. The relative hardness can be determined by scratching each with the others.

Which are the two most common rock-forming minerals of the earth's crust?

(b) Examine with the lens the different rock samples—granite, trap rock, schist, shale, slate, limestone, marble, sandstone, and quartzite. Compare these with the mineral samples and try to determine from which minerals the rocks were largely formed. What kind or kinds of soil are formed from granite? From sandstone? From limestone? From shale and slate?

PHYSICAL AND CHEMICAL CHANGES.

Examine a piece of rock candy, noting color, crystalline form, hardness, and taste. Grind a piece to powder with the mortar and pestle. Has the taste changed? Dissolve a little of the powder in a small quantity of water. Taste the liquid to determine if the material still exists. The changes thus far have been physical changes. Now heat a little of the powder in a dish, slowly first, noting all the changes. Heat until no further changes take place, then allow to cool. Taste the residue. Note its color. What does the new substance resemble? Will it dissolve in water? What kind of a change has taken place?

SOIL COMPOSITION.

Material composing soils.—Examine carefully (hand lens may be used) several samples of soil in the field or classroom and note their physical make-up. Distinguish between *organic* and *inorganic* particles, between vegetable and mineral matter. Which contain more vegetable matter, the light or dark colored soils? Are the organic and inorganic particles distinct and separate, or do they adhere closely to one another? What is the source of the vegetable matter? The mineral matter?

Mineral base of soils.—Examine carefully these samples again and note the variation in size of the mineral particles. What name is given to the large mineral particles? Of what may these particles consist? What name is given to the fine, dustlike particles? Of what may these particles consist? What are the intermediate-sized grains called? Do you find particles of these sizes in greater or less abundance in all samples examined?

Mineral particles determined by sedimentation.—Place a tablespoonful of soil in a long pickle bottle and fill the bottle up to the neck with water; add a few drops of ammonia; shake well for at least three minutes. Set down the bottle and observe the settling of soil particles. The material which settles to the bottom during the first few seconds is coarse sand or gravel. The material which continues to settle more slowly during the next few minutes is silt. The water is turbid after settling has apparently ceased because of the fine clay particles in suspension. Put aside the bottle and find how long some of the fine particles will stay in suspension.

FIELD STUDY.

Where practicable, field trips or excursions may be made for studying the rock formation of the community, noting relations between the prevailing rocks and the types of soil. It should also be noted whether the particular areas of soil visited are of residual or transported formation.

REVIEW QUESTIONS, LESSON I.

1. Of what two parts does soil largely consist? From what does each part originate?
2. Name some common rock-forming minerals. What are sedimentary rocks?
3. What is humus? Explain how it is produced in the soil.
4. What is a physical change? A chemical change? A biological change? Give examples of each.
5. What is an element? A compound? Give examples of each.

6. What are residual soils, and what kinds of residual soils are formed from sandstone, limestone, and granite?
7. What is loess, and how is it produced?
8. Why are alluvial soils often found to be very coarse in the subsoil?
9. What are the characteristics of glacial soils, and how are they related to the rocks from which they were derived?

LESSON II. THE SOIL AND PLANT GROWTH.

Under favorable conditions of sunshine and heat, aeration and moisture, plants grow from materials furnished to them from the air and from the soil. Since plant-food materials are constantly being removed from the soil in the growth and harvest of crops it is important to understand to what extent the different farm crops draw upon the soil for plant food, what amounts of these materials are contained in the different soils, and by what means the soil replenishes the essential food materials for the needs of crops.

What the air and the soil furnish to plants (Ref. Nos. 1, pp. 16-20, 31-34; 3, pp. 477-482).—The atmosphere is one of the sources from which plant food is derived. The air is made up almost entirely of gases, nearly four-fifths being nitrogen, about one-fifth oxygen, and only four one-hundredths of 1 per cent, or about 4 parts in 10,000, carbon dioxid. Oxygen is used directly by plants as by animals. The air passes into the leaves, where a small amount of oxygen is taken up and combines with other materials in the cells. Carbon-dioxid gas is a compound of the elements carbon and oxygen. (See p. 4). In sunlight the green leaves of plants decompose this gas, fixing the carbon and returning the oxygen to the air. The carbon thus used comprises about 50 per cent of the dry weight of plants. Nitrogen is not taken directly from the air by plants, although it is a most important plant food.

When a quantity of any green farm crop is cut and allowed to wilt and cure in the sun it loses a large part of its weight by the evaporation of the water which it contains. If the cured material is heated in an oven at 212° F., the temperature of boiling water, it again loses weight for a time from evaporation. What remains is called dry matter. If this be burned, the organic matter passes away as gases while the mineral matter remains as ash. The water from evaporation contains the elements hydrogen and oxygen; the escaping gases include the elements carbon, hydrogen, oxygen, and nitrogen, and the ash contains compounds of the elements potassium, phosphorus, calcium, magnesium, iron, sulphur, chlorine, sodium, and silicon. All of these elements except carbon and a small quantity of oxygen were secured by the growing plants from the soil.

It has been found by chemical analysis that the 13 elements mentioned above are present in all growing crops, but they vary in

quantity with different crops and with the stage of development of the plants. In general, the mineral elements and the nitrogen make up only about $1\frac{1}{2}$ per cent of the dry weight of plants, while the carbon, hydrogen, and oxygen comprise about $98\frac{1}{2}$ per cent of the total dry weight. While silicon, sodium, and chlorine are present in growing crops, these elements do not appear to be indispensable to the successful growth of plants. Attempts to grow plants without any of the elements carbon, hydrogen, oxygen, nitrogen, potassium, phosphorus, calcium, magnesium, iron, or sulphur have resulted only in failure. These elements have been called, therefore, the 10 essential elements of plant food. Whenever all conditions favorable to the best growth have been furnished to plants, with the exception that some one essential element was supplied only to a limited extent, the plants have never developed beyond the point made possible by the element which was limited in supply. When this principle is applied to crop production, it means that no matter how favorable the water supply, the tilth, and other essentials for growth may be, the harvest will never exceed what is made possible by the element which relatively is least supplied to the crop from the soil. The element of plant food thus limiting growth is called the limiting factor in crop production. The elements commonly considered as limiting crop production are nitrogen, phosphorus, and potassium. The management of soils so as to build up the supply of these elements of plant food is specially treated in Lessons VI and VII.

How soil materials are utilized by plants (Ref. No. 3, pp. 404, 405, 412-418; or No. 10, pp. 166-174).—Soil materials must be dissolved in water before plants can absorb them. The plant-food elements of the soil go into solution in the form of compounds called salts. A salt results from a chemical reaction between an acid and a base. An acid is a substance which will turn blue litmus paper red, while a base is one which will neutralize an acid and will turn red litmus paper blue. Vinegar contains an acid, while slaked lime is a base. When muriatic acid is added to slaked lime they react and form calcium chlorid, which is a salt. Calcium phosphate, potassium sulphate, and sodium nitrate are examples of salts which serve as sources of plant food. While these and all other salts must be dissolved before they can be utilized by plants, it is not necessary or even desirable that large quantities of plant food be in solution in the soil at any one time. Plant-food substances in solution or in condition to become so from the action of natural agencies are called available; those not in condition to become soluble for plant use are said to be unavailable.

Plants during growth absorb the soil solution through many small projections called root hairs. These root hairs constantly develop anew near the ends of protruding rootlets and keep in close contact with soil grains and immersed in the water film surrounding soil

grains. Root absorption of liquids takes place by a physical action called osmosis. If a bladder be filled with a solution like the white of an egg, the opening tightly tied with string, and the bladder put in a dish of salt dissolved in water, there is set up a movement of the salt solution through the walls of the bladder to the inside which soon distends the bladder to a considerable extent. The movement of liquid in this case is mainly inward, as colloidal solutions like the white of an egg pass but slowly through porous membranes. This movement will continue until the tension force from the stretch of the bladder walls equals the force which causes the water to move inward. The cause of the movement of the water through the bladder is called osmotic pressure. The illustration helps one to understand the movement of soil solution into the roots of growing plants. The walls of the cells composing the roots, like a bladder, are permeable to dissolved salts only, and the dilute salt solutions of the soil pass by osmosis through the cell walls into the denser solutions of the cell sap. When all the root cells become sufficiently turgid (distended) the plant-food solution is forced into the minute vessels and channels of the stem structure and upward to be utilized for growth.

Three conditions are necessary for the osmotic absorption of water by plant roots. These are: (1) A favorable temperature of the surrounding soil; (2) a supply of fresh air; and (3) a suitable quantity of water. Some plants are able to absorb water at temperatures as low as the freezing point, but this is not common. It has often been observed that the growth of potted plants is hindered by lowering the temperature of the soil by the use of cold water. A proper supply of water in the soil is indispensable for root absorption, but an excess of water shuts out the air from the soil and causes carbon dioxid poisoning and death of the root hairs, due to improper respiration or breathing in their cells. Soils are also made cold by much evaporation due to excess of water. The matter of air and water supply in soils will be considered at length in Lessons IV and V.

How elements of soil and air function in plants (Ref. No. 1, p. 37).—By supplying varying quantities of available mineral plant foods to growing plants with a suitable supply of moisture in the soil some conclusions have been reached concerning the functions of the essential elements. When a liberal supply of materials giving up nitrogen has been used, plants have produced rank, green foliage, often to the detriment of seed production. Therefore, when leaves and stems furnish the food part of plants, as with cabbage and celery, the soil growing these crops should be well supplied with available nitrogen. Seeds and grain contain relatively large quantities of the element phosphorus in combination. A good supply of available phosphorus-bearing materials hastens the maturing of plants and is particularly essential in the seed and grain crops.

Phosphorus also seems to bear an intimate relation to the development of plant cells. Potassium and calcium are closely allied with stem and root structure. A liberal available supply of these elements favors stiff, strong stems in grain and other crops. Potassium is also essential in starch formation. A good supply of available potassium in soils is needed, therefore, for root crops. Sulphur has an important function in cell structure. Iron is necessary in the forming of chlorophyll grains which give the green coloring to leaves and which, in the presence of sunshine, aid in the manufacture of starch in the leaves, largely from carbon dioxid and water. Carbon, together with water, composes a large percentage of plant structure and is the basis of all organic substance. Oxygen not in combination with other elements enters the plant and causes the breaking down, or oxidation, of other materials in the plant.

Soil materials removed by crops (Ref. No. 3, pp. 418-420).—In nature, as plants mature and decay, the soil materials used in plant growth are largely returned to the soil. The loss to the soil of inorganic or mineral substances by leaching and erosion is usually counter-balanced by the natural agencies of disintegration, while the organic or vegetable decomposition enriches the soil in nitrogen and returns the mineral substances again to the soil. Mineral compounds from vegetable decay, it should also be noted, become more readily available in the soil than do the minerals from rocks. Under ordinary farm practice, on the other hand, soil materials are removed in crops, waste occurs in connection with the management of manures, straw, and plant residues, and the soil often leaches and erodes very readily. All of these things deplete the fertility of the soil. The plant-food elements removed by crops vary with the yield, the crop grown, and the available materials in the soil. A reliable table showing the average quantity of nitrogen, phosphorus, and potassium removed from the soil by crops is found in reference No. 5, page 154.

Plant-food materials contained in soils (Ref. No. 5, pp. 58-60).—The amounts of the essential plant-food elements in soils are extremely variable. Since the nitrogen in soils comes almost entirely from vegetable decay, the supply of this important element depends upon the plant materials returned to the soil and the activity of the agencies of decomposition. The total supply of the mineral elements present in the soil, as stated in Lesson I, depends largely upon the original rocks from which the soil was formed. The quantity of materials available for plant growth, it must be understood, depends upon good soil management as well as upon the type of soil formation. Hopkins says:

We can assume for a rough estimation that the equivalent of 2 per cent of the nitrogen, 1 per cent of the phosphorus, and one-fourth of 1 per cent of the total potassium contained in the surface soil can be made available during one season by

practical methods of farming. Of course, the percentage that can be made available will vary very much with different seasons, with different soils, and for different crops; and yet with normal soils and seasons and for ordinary crops the above percentages represent roughly about the proportion that is liberated from our common soils of the elements that limit the yield of the crop.

The meaning and value of chemical soil analysis.—Chemical analysis of soil is a means of helping to determine how areas of soil which are unproductive should be managed. A few things should be understood with regard to soil analysis: (1) It is highly important that the surface and subsurface soil samples be representative of the area examined. To this end it is advisable to get directions from the analyst before taking the samples of soil to be analyzed. (2) The chemical analysis of a sample of soil will probably not detect a bad physical condition which may be an important factor of its non-productiveness. For example, poor drainage of a soil may not be evident from its chemical analysis. (3) A soil may be dead, so to speak, due to microbiological inactivity, or other causes. The regular process of soil analysis probably would not detect this condition. (4) Chemical soil analysis does give the amounts of nitrogen, phosphorus, and potassium in the samples of soil analyzed, and if the samples are representative the total quantities of these essential elements of plant food per acre to a stated depth can be quite accurately estimated. The supplies of these elements available for plant growth may also be indicated by the analysis, but the reliability of the methods used in determining availability is still a matter under discussion by soil chemists. It is safe to say that chemical soil analyses often indicate what is the limiting factor in crop production in the soil. (5) In soil analysis a test is made for acidity, and if acid is found this is stated in terms of the amount of lime necessary to correct the condition, and from this the application most practical for the cropping system in use may be estimated.

The relation between the terms nitrogen, phosphorus, and potassium, and the corresponding terms ammonia, phosphoric acid, and potash, commonly used by soil analysts, will be explained in subsequent lessons.

The possibility of exhaustion of soil nutrients (Ref. No. 3, p. 419).—It is a matter of common knowledge that the cultivated soils of the United States, under the ordinary farm practices, frequently become less and less productive. There are various causes for this decline in productiveness. The removal of plant-food materials in cropping, which has already been referred to, is one of these. The leaching of soluble compounds into the drainage water of soils is likewise a source of considerable loss. It has been found in general that soils have greater retentive power for compounds containing phosphorus and potassium than for compounds containing nitrogen. Sodium

nitrate, a common source of nitrogen, is readily leached from the soil. Very little loss occurs from the leaching of phosphorus compounds. The amount of leaching also varies considerably with the type of soil. Soluble materials are leached more readily from sandy soils, for example, than from clays. Erosion is another cause of much loss of fertility from soils. Leaching and erosion can both be avoided to a large extent by keeping the soil covered with plant growth.

There are several ways and means by which plant-food materials are replenished in the soil. The removal by different agencies of surface-soil materials subjects the subsurface to increased action from the agencies of disintegration and decomposition which set free plant food. Then the dissolving action of water in the soil is constantly increasing the availability of the mineral nutrients. The return of organic matter in the form of manures, straw, and plant residues from crops and weeds is doubtless the best means at the command of the average farmer for keeping up the productiveness of his soil. Various substances in the form of commercial fertilizers are now much used, the quantity and nature of these materials depending upon the type of soil, the crops grown, and the judgment of the user.

EXERCISES, LESSON II.

Materials needed.—Balance; porcelain dishes; sodium hydroxid; red and blue litmus paper; muriatic acid; burnt lime; covered fruit jar; glass tubing; one-holed stoppers; rubber tubing; limestone; marble slab; some small boxes; sandy soil and a few kernels of corn; sealing wax; large-mouthed pickle bottles; and eggs (to be furnished by the class).

Composition of plants.—Take a growing plant and weigh it. Record the weight. Cut up and put pieces into a porcelain dish. Heat very gradually, causing the plant to wilt and dry out, but do not apply enough heat to cause charring or burning. While the drying is being done, hold a clean, dry glass plate over the containing dish. Remove glass at times and note from its appearance what is being expelled from the plant. After the plant is thoroughly dried, cool and weigh again. Record the weight. What percentage of the total weight passed off as moisture? Now burn the dried substance until only ash remains. Weigh again. Record the weight and figure the percentage of ash. The ash contains the mineral materials taken from the soil. The part consumed by burning represents what was formed from the carbon dioxid of the air and the water and nitrogen from the soil.

Formation of a salt.—Dissolve a piece of sodium hydroxid about the size of two peas in a *small quantity* of water. Dip the tips of forefinger and thumb into the solution and rub together. Note the feeling, then wash finger and thumb. Put about one-fourth teaspoonful of this solution into a separate dish (keeping remainder) and add about 5 teaspoonfuls of water. Dip finger into this solution and touch to the tongue. Note taste, then spit out. Put small piece of red litmus paper into this weak solution. What happens? Sodium hydroxid is a base. After noting all its properties, discard this *weak* solution.

(a) Put about 10 teaspoonfuls of water into a dish. Add *not over* 5 drops of muriatic acid and stir. Touch tip of finger to solution and taste, but *do not swallow*. After

noting taste, put a small piece of blue litmus paper into the solution. What happens? After noting properties of the acid, discard this solution.

(b) Now take the *original strong* solution of the sodium hydroxid and very slowly add muriatic acid, *drop by drop*. Place piece of blue litmus paper in the solution, keep stirring while slowly dropping in the acid, and stop adding acid *the instant* that the blue litmus paper turns red. Now pour the solution into a porcelain dish and boil until all the liquid has evaporated and the remaining substance is completely dry. Taste the residue. What is it? It was formed from a chemical reaction between an acid and a base.

Carbon dioxid of carbonic-acid gas.—Put a piece of burnt lime one-half the size of your fist into a pint fruit jar. Add water to slake the lime. Now add more water until can is nearly full, put on cover, shake thoroughly, then set away to settle. (One can of the liquid will probably suffice for the use of the class.) Put a glass tube through a one-holed stopper. (*Be careful* not to break the tube and cut the hands.) Fit a piece of rubber tubing over the end of the glass tube. Put a small piece of limestone into a bottle in which the stopper containing the glass tubing fits. Pour a little of the prepared limewater into one glass dish, or bottle, and a little water into another. Dilute not over one-half teaspoonful of muriatic acid by adding about 4 or 5 teaspoonfuls of water. Have the bottle containing limestone, the bottle containing limewater, and the bottle containing water all in readiness, then pour the dilute acid upon the limestone and quickly insert stopper containing glass tube. Put end of rubber tube into bottle containing limewater so that end of tube is below the surface. After the gas has passed into the limewater for a little time, remove the rubber tube and place it under the water in the other glass dish or bottle. The gas escaping from the bottle containing limestone is carbon dioxid. What effect does it have upon limewater? Put a small piece of blue litmus paper into the water through which the carbon dioxid has been passing for some time. What happens? Do you see why the gas is sometimes called carbonic-acid gas? Wash one of your glass dishes or test tubes thoroughly, then add another small quantity of limewater. Use a glass or rubber tubing and blow your breath through the limewater. What does your breath contain? Pour another small portion of limewater into a clean glass and let it set for some hours, or even days, in a place not dusty. What gas is shown by this experiment to be present in the air? The result can be shown much more quickly by using a bicycle pump and forcing air through the limewater.

Root hairs and the action of roots.—Place a square piece of polished marble slab at the bottom of a box about 4 or 5 inches deep, with the other dimensions equal to that of the slab. Place the polished surface up and fill the box with moist soil of a sandy nature. Plant a few kernels of corn in this soil. Put in a warm place and keep the soil moist. When the plants have grown at least 6 inches high, remove them very carefully. Note how the rootlets cling to the soil grains. Now clean the rootlets carefully with water and examine near the ends with the magnifying glass for root hairs. Remove the soil from the box and note the effect of the roots on the polished marble.

Osmosis.—Using sealing wax and a piece of glass tubing about 4 or 5 inches long; seal the tubing on the small end of an egg. Very carefully break and remove the shell, or outer covering, from a small portion of the other end of the egg. Fill a wide-mouthed pickle bottle with a strong solution of common salt and set the egg, tube upward, in the opening of the bottle. Now run a hatpin down the glass tubing and carefully break through both coverings of the end of the egg. Keep the bottle full of water and leave the egg set up in this way for several hours. What results? Stick the hatpin into the solution within the egg and taste. Do you now begin to understand how plants get dissolved mineral foods from the soil?

REVIEW QUESTIONS, LESSON II.

1. What chemical elements are essential to the growth of plants? In what condition are they utilized by plants?
2. What is a salt? Give example. Name some properties of acids and of bases which you have discovered. Give examples of acids, bases, and salts.
3. Tell what you understand by the limiting factor in crop production.
4. What are root hairs? Describe the process by which plants absorb materials from the soil.
5. Is it possible that plants might not be able to get enough plant-food material for their growth, even though the soil may contain sufficient quantities of it? Explain.
6. Mention a special function of potassium in plants; of phosphorus; of nitrogen.
7. How much nitrogen, phosphorus, and potassium are taken from the soil in removing a 100-bushel crop of corn? A 50-bushel crop of wheat? Three hundred bushels of potatoes? Six hundred bushels of apples? Four hundred pounds of butter? (See Table 23, Ref. No. 5, p. 154.)
8. Of what value is chemical soil analysis to the farmer? Discuss.
9. Give the means of removing and the means of replenishing plant-food materials in soils.
10. What is adsorption?

LESSON III. PHYSICAL PROPERTIES OF SOILS.

In farm practice the term "soil" is somewhat loosely used to include the furrow slice. It is commonly about 6 to 8 inches in depth, comparatively friable and porous, and in humid climates is darker and contains more organic matter than the part beneath, called the sub-soil. These two parts are better designated by the terms surface soil and subsurface soil, both parts being comprehended in the general term "soil," which usually includes a layer of about 4 feet, or the depth to which the roots of farm crops commonly extend. In connection with tillage, soils are also spoken of as being heavy or light, depending upon whether they are hard or easy to work. Clay soils are hard to till, due to their fineness of particles and their stickiness. Sandy soils till easily, but are coarse grained and really heavier than the clays. All soils are mixtures of different-sized particles. The size of the particles determines the *texture* of a soil. *Structure* has to do with the arrangement of the particles of soil and is independent of their size. When the structure of soil particles is such as to be highly favorable to the growth of crops the soil is said to be in good *tillth*.

TEXTURE.

(Ref. No. 2, pp. 70-76, or No. 3, pp. 84-86, 97, and 102.)

Mechanical analysis.—To study texture the inorganic soil particles are separated into a number of grades according to size. This separation is called mechanical analysis. Fine wire sieves, carefully constructed, are employed for separating the coarser sands into different grades, and bolting cloth, such as is used in flour mills,

is used for separating the finest sands. To separate the still finer particles constituting silts and the clays it is necessary to shake the remaining portion of the soil thoroughly in water and then at different periods of time to draw off that which remained suspended during the previous period, allowing it to stand in another vessel for a longer time. By using these methods any number of different grades may be established. As a rule, however, but seven grades are separated. These have the following names and diameters expressed in millimeters and inches.

TABLE I.—*Grades and size of soil particles.*

Grade of soil.	Millimeters.	Inches.	Grade of soil.	Millimeters.	Inches.
Fine gravel.....	3 to 1	0.12 to 0.04	Very fine sand.....	0.10 to 0.05	0.004 to 0.002
Coarse sand.....	1 to .5	.04 to .02	Silt.....	.05 to .005	.002 to .0002
Medium sand.....	.5 to .25	.02 to .01	Clay, all particles less than.....	.005	.0002 and less.
Fine sand.....	.25 to .1	.01 to .004			

The measurement of the diameter of these particles is made by means of a microscope.

Mechanical composition of various soils.—All soils contain some particles of each of the seven grades as previously given, but the proportion varies greatly. Heavy clay soils are largely made up of silt and clay particles with small quantities of the different-sized sands, while sandy soils are made up of relatively large quantities of the various grades of sand and correspondingly smaller quantities of silt and clay. It is therefore desirable to subdivide soils on the basis of the relative proportions of the different-sized grains. Soil investigators recognize on this basis coarse sand, sandy loam, fine sandy loam, loam, silt loam, clay loam; and clay.

These different classes of soils have the average mechanical composition or texture shown in Table II.

TABLE II.—*Average texture of important classes of soils.*

Class of soil.	Mechanical analysis giving average percentage of soil separated in each class.						
	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Coarse sand.....	5	15	25	30	10	10	5
Sandy loam.....	5	10	10	25	15	20	15
Fine sandy loam.....	1	4	5	20	25	30	15
Loam.....	1	3	4	15	20	40	17
Silt loam.....	1	1	2	6	10	60	20
Clay loam.....		1	2	5	15	42	35
Clay soil.....		1	2	5	12	30	50

Quantity of surface exposed in soils.—The area of the total surface of the particles in a soil of fine texture is much larger than in one of coarse texture. The principle is illustrated by considering the effect

of dividing a block of wood 1 foot on each edge by sawing it through in the middle in the three directions. This will produce eight cubes 6 inches on each edge. The large cube will contain 6 square feet of surface; each of the smaller cubes will measure 6 inches, or one-half of a foot, on each edge and will contain one-fourth of a square foot on each surface. This multiplied by 6, the number of surfaces on a cube, then by 8, the number of small cubes, gives 12 square feet of surface. The area is therefore doubled by the division. The same division of each of these smaller cubes would again double the area, and so on. In the same way the division of a grain of sand into eight smaller particles having one-half the original diameter would multiply the entire surface exposed by 2. A cubic foot of coarse, sandy soil has about 40,000 square feet of surface, or nearly 1 acre. A cubic foot of sandy loam has about 65,000 square feet of surface, a cubic foot of clay loam nearly 105,000 square feet, and a heavy clay about 200,000 square feet, or nearly 5 acres. It should be noted, however, that under certain conditions the particles in soils of fine texture tend to flocculate or collect in small aggregates (see p. 20), thus reducing the effective area of exposed surface.

Relation of effective soil surface to fertility.—That the qualities of soils are largely influenced by the size of the soil grains is due to the fact that many of these qualities actually depend on the area of the total effective surface of all the soil grains in the mass of soil that the roots of plants occupy. The water held by the soil after draining is in the form of fine films surrounding the soil grains, and therefore the quantity depends on the extent of surface of the soil grains. Chemical and microbiological processes forming available plant food also take place on the surface of the soil grains. The finer the particles of any soil the greater is the relative quantity of available plant-food materials carried in the soil solutions. The total feeding area of plant roots is therefore increased as the size of the particles composing the soil is decreased.

STRUCTURE.

(Ref. Nos. 3, pp. 115-116; 184-197; 10, pp. 99-101.)

Plasticity and granulation.—The particles of a soil when wet have a tendency to stick together and to adhere to other objects with which they come in contact. This property of stickiness or ability to be molded is called plasticity. Coarse-textured soils show this property only to a very small degree. In soil-management studies, therefore, plasticity need be considered only in connection with the fine-textured soils, especially the clays. The plasticity of soil is due principally to the size and arrangement of the soil particles, the water present in the soil, and the materials contained in the soil solu-

tions. If clay soil is tilled when wet, its smaller particles seem to become more closely fitted into the spaces of the larger particles, and in this very plastic condition the soil is said to be *puddled*.

As wet soils dry out the water films surrounding the particles become thinner, which causes a contraction of the soil mass. This contraction causes separations between particles having least cohesion, which results in irregular cracking and the formation of soil masses of various sizes. Highly plastic clay soils which have become puddled form into large masses upon drying, and when tilled break up into clods. On the other hand, when rightly managed, clay soils upon drying form into small, irregular masses, which by tilling form a crumblike structure. This property is called *granulation*. The granulation of soils has a very important influence on the growth of crops, since it permits the excess of water to drain off more readily than would be the case if all the soil grains were as closely arranged as possible, and it offers the roots of the plants an opportunity to penetrate the soil much more readily than they could otherwise do. It also gives the air better access to the growing roots and to the microorganisms causing changes in the soil.

Agencies producing granulation.—The principal agencies which affect granulation in soils are: (1) Good drainage. Where land is well drained any excess of water quickly passes away instead of saturating the soil and thus inducing puddling and the formation of solutions which hinder granulation. (2) The use of lime. The addition of lime to clay soils causes a flocculation, or gathering into aggregates of materials suspended in the soil solutions, and thereby reduces plasticity and promotes granulation. (3) Insects and plant roots. The borings of insects and earthworms, and the penetration of plant roots far into the subsurface soil, deepen the zone of granulation. (4) Decaying vegetable matter in the soil. It is believed that the humus in the soil becomes distributed over the surfaces of soil grains and through the solutions of the soil, reducing its plasticity and permitting better granulation. At any rate, it is a practical fact of common farm experience that plowing manure, straw, and plant residues deeply into the soil produces a loosening, granulating effect which makes tillage easier and adds to productiveness. (5) The growth of grasses. The fine, fibrous roots of grasses, completely permeating the openings of the surface soil, attach themselves thoroughly to the soil particles and gradually develop a condition of granulation. The good tilling properties of land which has been in grass for several years are well known. (6) Tillage operations. Soil must be tilled at the right time and with the right implements to secure the best granulation.

Pore space in soils (Ref. Nos. 10, pp. 101, 102; 3, pp. 108, 109).—Pore space in soils may be thought of as the space not occupied by the

solid soil particles and the moisture film surrounding these particles. It is the space in well-drained soils which is open to the circulation of air and other gases and to the growth of plant roots. The total pore space in any soil depends less upon the size of soil particles than upon the arrangement of these particles. From the standpoint of pore space the granules in soil are similar to single soil grains. The pore space in sandy soils under ordinary field conditions is about 40 per cent of the total. In clay loams the granulation is commonly such that 55 per cent of the total volume of the soil is pore space, only 35 per cent being occupied by solid matter; while in fertile heavy clays granulation may be present to such an extent that 65 per cent of the total volume is pore space. Ample pore space in soil to a depth of 4 feet or more is very essential to a thorough distribution of plant roots, and a free circulation of air in the soil is indispensable to the growth of farm plants.

Circulation of air in the soil.—Some of the principal causes of the circulation of air in soils are: (1) Water movements in the soil. Any movement of water through the soil has an effect upon the circulation of the soil air. A good example of this is seen in underground drainage. Following rains, or accompanying irrigation in arid lands, as the water passes downward through the soil into the drains, the atmospheric pressure forces the air into the pore spaces opened by the water passing out. (2) Changes in barometric pressure. Variations in the pressure of the atmosphere, indicated by the barometer, produce currents of air, or winds, which pass over the earth's surface. These causes of surface movements of air also affect subsurface movements of soil air, but to a lesser degree. (3) Changes in temperature, due to day and night. After sunset the atmosphere cools more rapidly than the earth's surface. The warmer air of the soil, being lighter, moves upward through the pore spaces and into the atmosphere, while an equal volume of cooler air above the surface moves downward into the soil to take its place. (4) Diffusion. It is a physical law that when two gases are in contact they always mix, or diffuse. Carbon dioxid given off in the soil from the roots of plants and from vegetable decay, together with other soil gases, gradually diffuses in the soil air and thereby helps to produce a certain kind of circulation.

Among the causes influencing pore space and soil-air circulation those most under control in soil management are drainage and granulation. If soils are filled with water there can be no circulation of air therein. On the other hand, if clay soils are so managed as to become puddled and baked, the lack of pore space and granulation will result in poor circulation of air through them and thus prevent the successful growth of plants.

TILTH.

(Ref. No. 2, pp. 277-283.)

Soil management to produce good tilth.—Ample pore space and thorough granulation in a soil are two of the most important factors of good tilth. It is impossible in a brief treatise of this kind to formulate rules for tillage covering the use of all farm implements, for all farm crops, grown upon all types of soil. But a thorough knowledge of the principles involved and the ends to be attained is of greater value in farm practice than any set of rules. It is only by experience, together with a mastery of the principles of soil management, that the best tilth will be secured and the best results in farming produced. This is especially true of the different clay soils, many of which are fertile, but all of which require intelligent management.

EXERCISES, LESSON III.

Materials needed.—One-pound baking-powder cans; a balance or scales, 2 quarts each of dry sand, clay, silt loam, clay loam, sandy loam, loam; several 1-inch wooden cubes; any simple apparatus to measure cubic inches of water; set of soil sieves; pie tins, or saucers.

SOIL TEXTURE.

Heavy versus light soils.—Take two 1-pound baking-powder cans of equal weight and fill one level full with air-dried sand. Fill the other with finely divided air-dried clay or silt loam. Compare the weights of these two volumes of soil. Which does the farmer usually consider as light soil? Why? Why is the other commonly called a heavy soil? To which soil may the term fine textured be applied? Describe the texture of the light soil.

Soil classes based on size of soil grain (Ref. No. 3, p. 77).—Obtain dry samples of sand, clay, silt loam, sandy loam, clay loam, and loam. Examine each class carefully with a hand lens and note the following characteristics: Comparative size of soil particles; the feeling between the fingers when wet, whether gritty, sticky, or velvety; kind of soil particles based on texture.

(To THE LEADER.—A tablespoonful of each sample of soil may be placed in separate small dishes and labeled to enable the members of the class to work alone or in pairs. After the members have become familiar with each soil class, unknowns may be passed out for identification.)

Mechanical analysis.—Take about half of a pound baking-powder can of two or three different kinds of dry soil. Weigh each sample separately and record. Take one kind of soil and pour upon the coarsest soil sieve. Shake until no more of the material passes the sieve. Retain the part passing through. Weigh the part retained by the sieve and record the weight. Take the part passing through the sieve, repeating the process as above with the next finer sieves in order and recording the weights, until all the sieves have been used. Compare percentage of separates with table on page 18, and try to determine the correct names for classes of soils used.

Texture and film water (Ref. No. 2, pp. 157, 158).—(a) Take eight 1-inch cubes and build them up into a 2-inch cube. How many square inches of surface does this 2-inch cube have? Determine the total number of square inches of surface on all the smaller cubes.

Cutting a cube in three directions increases the number of cubes how many times? How many times does it increase the surface area?

(b) Let the original 2-inch cube represent a soil grain of a coarse-textured soil. Cut it in three directions, and cut each resulting cube again in three directions. Into how many cubical particles is the original soil grain now divided? The total surface area of these particles is now how many times that of the original soil grain?

A soil made up of these resulting particles is how much finer textured than soil made up of particles like the original soil grain? Which soil will hold more film water? Why?

Texture and pore space.—Secure two 1-pound baking-powder cans and make them water-tight by use of a little paraffin. Fill one within half an inch of the top with dry sand, and the other with dry clay loam and silt loam. Measure carefully the cubic inches of water required to saturate the soil in each can. Apply the water to one edge of the can only as fast as it is absorbed by the soil. This will allow the air in the soil pores, or spaces, to escape. Determine the number of cubic inches of soil in each can ($3\frac{1}{4}$ times radius squared times height of soil column equals volume) and compare each volume of soil with the volume of water required for saturation.

What percentage of the volume of sand is water?

Where is this water in the soil? Draw a diagram showing the relation of the sand grains to the water. What, then, is the approximate percentage of pore space in the sand? In the clay or silt loam? Explain fully why clay or silt loam is more porous than sand. When is a soil said to be saturated? What is the relation between the porosity of a soil and its texture? Between porosity and weight of dry soil?

Plasticity.—Place small quantities of a clay soil and some other class of soil upon two different pie tins or saucers. Add water slowly to each and continue to stir until the samples can be molded like dough. Which soil shows the greatest degree of plasticity? Add water and mix each sample until the soils have become puddled. Set aside to dry. What happens to the two samples when entirely air dried?

Granulation.—Put a small sample of dry clay soil upon a dish and add water without stirring so slowly that the soil absorbs it as fast as added. Do not add water enough to saturate the soil, only add what would be held by a well-drained soil. Set the soil aside to dry and try to stir at just the time when best granulation can be effected. How does the structure of this soil now compare with the dried-clay sample that was puddled?

Field trips.—If possible, field trips should be made to study soil classes. With a spade dig down through the surface soil and partly into the subsurface. Make a smooth, perpendicular edge. Now note line between surface and subsurface and measure the exact depth of the surface soil. Observations as to differences of color, texture, and structure should also be made. What has caused these variations?

REVIEW QUESTIONS, LESSON III.

1. What is meant by texture of soils? By structure?
2. How do you distinguish between heavy and light soils?
3. By what process is the texture of the soil determined?
4. Compare the sand, silt, and clay content of a fine sandy loam with that of a clay soil.
5. Mention some ways in which the fertility of a soil is influenced by its texture.
6. Explain fully the influence of the area of surface of the soil grains on the water-holding capacity of soils.
7. What is meant by soil granulation? Soil tilth?
8. Mention several agencies which develop granulation in soil.
9. How is puddling of soils produced?
10. What is meant by pore space in soils? Draw diagram to illustrate.
11. About what fraction of clay loam soils under the ordinary field conditions is pore space?

12. Give some influences which cause a circulation of air in soils.
13. Why is air circulation in soil important?
14. Discuss the different factors which have to do with good tilth.

LESSON IV. THE WATER SUPPLY OF THE SOIL.

The soil is a reservoir which stores a part of the water supplied to it by rain and irrigation, giving it up again to meet the needs of growing plants.

Water-holding capacity of soils (Ref. Nos. 2, pp. 157-162; or 3, pp. 210-218; 10, pp. 119-122).—If the surface soil of a field is thoroughly saturated with water for some time, most farm-crop plants stop growing, because the small amount of oxygen dissolved in the water will not suffice for the needs of the plants and further supplies can not penetrate the saturated soil. If land with a porous subsurface or an underdrainage system be examined after a thorough soaking with rain, it will be found that the water remaining is held in the form of films surrounding the individual soil grains and the smaller clusters of soil particles. The excess of water which has drained away under these conditions is called drainage or gravitational water. (Ref. No. 10, pp. 104, 105.) That which remains is called capillary or film water. (Ref. No. 10, p. 106.)

Since capillary water exists as a film surrounding the soil grains and therefore depends on the area of these particles, fine-textured soils can hold more water than coarse-textured soils. Moreover, this capillary water in the soil not only forms films around the soil grains, but these films are continuous from the surface downward in such a way that the moisture in the subsurface soil forms a weight on the films above, just as the lower links in a chain hanging by one end produce the weight supported by the upper links. The result of this is that the films near the surface in the soil are stretched by the capillary moisture below, so that a soil layer which is a number of feet above saturated soil can hold less capillary water than a layer only a few inches above saturated soil. The amount of capillary moisture held by the soil after a heavy rain depends, therefore, not only on the texture of the soil, but on the distance to the saturated subsurface soil on the ground-water table. The thickness of these films also varies with the temperature of the water. Films of warm water are drawn out considerably thinner than those of cold water. As a result of this principle, as soils get warmer during the summer, the quantity of capillary water diminishes.

Organic matter and water-holding capacity (Ref. No. 3, p. 218).—Vegetable matter in the soil in various stages of decomposition has a strong power to absorb and hold water. In a well-advanced stage of decay, as with muck and humus, organic matter can hold several times its own weight of water and very much more than the mineral

part of the soil can hold. In clay soils humus also has a considerable indirect influence on water-holding capacity through its power to affect granulation.

The total quantity of water held by different soils when saturated has been found to vary from about 40 per cent of their dry weight in coarse sand to about 55 per cent in well-granulated clay, and up to over 300 per cent, or three times its dry weight, in muck. The quantity of capillary water which these same soils have been found to hold varies from about one-fourth of the amount held upon saturation in coarse sand to over one-half in well-granulated clay, and up to nearly the total amount in muck. The larger capillary capacity of the muck is due largely to its high absorptive power. (See tables, Ref. No. 3, pp. 154-162.)

Water available to plants (Ref. No. 3, pp. 200-202).—Crops growing in soil are unable to take all the water which it holds. If soil in which plants have died for lack of water is thoroughly dried in an oven it will be found that there is expelled a small quantity of moisture which the plants were unable to secure. Coarse-textured or sandy soils retain very much less of such water than do the fine-textured clay loams or clays. This is because the plants are able to withdraw the water only to a given thinness of water film around the soil grains, and the larger total exposed surface of the fine-textured soils causes them to retain the larger quantity of water. It is evident, therefore, that only a part of the capillary water can be considered as available for growing crops. When the ground-water level is 10 feet below the surface the upper 4 feet of a very sandy soil can hold available water equal to a layer of about 3 inches in depth, a sandy loam $4\frac{1}{2}$ inches, a silt loam 6 inches, and a well-granulated clay soil $7\frac{1}{2}$ inches.

Water required by growing crops (Ref. Nos. 1, pp. 12-16; 10, pp. 12-17).—It was stated in Lesson II that water is used by plants directly as a plant food, and further, that water dissolves mineral substances in the soil and carries them to all parts of growing plants, where the mineral elements are utilized so as to perform their special function. In fact, all movements of substances within the plant take place largely through the medium of water. The larger portion of the cell sap of growing plants is composed of water. An average of 80 per cent or more of the green weight of staple farm crops is water. When the water supply from the soil is insufficient, the plant cells become shrunken, causing wilting. The temperature of growing plants is also regulated to some degree by the transpiration of water in the form of vapor from the leaves and stems. The quantity of water transpired, that is, given off as vapor to the surrounding air by growing plants far exceeds the quantity directly utilized to form plant substance. Experiments have shown that for every pound of dry

matter stored in ordinary crops an average of about 350 pounds of water is taken from the soil. This amount varies widely under different conditions and with different crops. Vivian says, "There is no doubt that the proper condition of moisture is the most important single factor in determining the fertility of the land, and that more soils fail to produce good crops for lack of it than for any other cause."

Variations in water requirements.—There is no necessary relation between the rate of growth and the quantity of water transpired by the plant. When all conditions are favorable to rapid growth the quantity of water transpired for each pound of dry matter produced seems to be distinctly less than when an essential element of plant food is lacking, or when disease attacks the plant, or any other cause exists which lessens the rate of growth. Moreover, there is a very marked influence of climatic conditions, especially temperature and humidity of the atmosphere, on the quantity of water which plants require. Most staple crops growing in the dry, clear atmosphere of Utah, for example, require from 50 to 100 per cent more water than in Wisconsin. But there also seems to be a marked difference among crops in respect to the relative quantity of water they require. Expressed by rainfall in inches, it has been found that in the eastern part of the United States and in Europe a crop of corn yielding 90 bushels per acre requires on the average 15 inches of water, one of oats yielding 75 bushels per acre requires 12 inches, 300 bushels of potatoes per acre, $6\frac{1}{4}$ inches, and 2 tons of clover hay, 9 inches. These figures include the water lost by evaporation from the surface immediately under the plant when careful tillage and mulching to prevent evaporation are practiced, as well as that transpired by the plant.

Depth to which roots extend for water (Ref. No. 10, pp. 86-93).—In climates which have frequent showers during the summer period, crops get most of their water comparatively near the surface and do not usually extend their roots for moisture more than 3 or 4 feet in depth. On the other hand, in regions in which there is a heavy winter rainfall and a long, dry summer, crops sown in the spring must go deeper and deeper for their moisture as summer advances and the rains cease. Some crops, especially alfalfa, are able to send their roots to great depths, often 20 feet or more. Under such conditions the water-holding capacity of the soil to great depths must be considered. In the Mississippi Valley, with considerable rainfall during the summer, one may be satisfied with a soil having a good water-holding capacity to a depth of 6 or 8 feet. On the Pacific coast and other parts of the country, where the rainfall comes all during one season, it is important that a fine-textured soil continue to a depth of 15 to 20 feet. This is particularly true for fruit trees.

Capillary rise of water (Ref. No. 4, pp. 30, 31).—Fortunately, crops are not entirely dependent on the moisture held in the layer of soil to

which their roots penetrate. After this has been partially dried out, as a result of the extraction of water by the growing crops, the water films are reduced somewhat in thickness and therefore have acquired greater tension and have the power of drawing up some of the moisture in the thicker films of the soil below. This capillary rise of water undoubtedly causes an important addition to the available supply. This movement of water varies greatly, however, in soils of different texture. It is of importance in coarse or sandy soils only when the ground-water level is within 10 or 12 feet of the surface, while in heavy clay soils it may come from considerably greater depths. The capillary movement is not rapid, but it is much faster in sandy than in clay soils. In the case of rapidly growing crops, especially on clay soils, in which the rate of capillary rise is slow, the water supply furnished in this way is altogether inadequate to maintain growth after the moisture in the surface soil has been reduced to the lower limits of good growing condition. It is, nevertheless, an important addition to the moisture already held in the soil.

Capillary rise of water in soils is illustrated by holding two glass tubes of very small but different-sized bores perpendicular, with the lower ends under the surface of water. In both tubes the water will rise above the surface level of the water in the containing vessel, but the column in the smaller tube will stand the higher. This rise of water in capillary tubes is due to two forces: (1) The attraction of the glass for water, which causes the water to creep up the tubes a little above the general level of the water surface within the tube; and (2) the tension, or stretch, which is on the surface of all liquids. If a dry needle is carefully placed upon a smooth surface of water, the needle will float, but can be seen to be causing a stretch of the liquid surface beneath it. This elastic tension of a liquid surface causes the surface within the tubes to tend to form a plane. The simultaneous action of these two forces noted will cause the water to rise within the tubes until the weight of the water therein equals the force of tension of the surface films. The column of water in the smaller tube, being the lighter, will rise to the higher level.

In soils, the openings between particles, or pore spaces, serve as capillary tubes, and the perpendicular rise of water behaves in accordance with the laws of capillarity. Fine-textured soils, therefore, have a higher rise of water from this cause than soils of coarse texture, although the rate of rise is much slower in the former. There are, however, other factors of practical importance affecting capillarity in soils which should be noted: (1) Some mineral salts in solution strengthen the surface tension of water and add somewhat to the rise of water in soils; (2) heat reduces the strength of the surface film of water and other liquids as well; and (3) some liquids, such as these from manures and decaying vegetable matter, have been found

to reduce the surface tension of soil water and so lessen to a slight extent the rise of water in the soil by capillarity.

Rainfall in relation to water requirements of crops.—According to a report from the United States Weather Bureau the normal annual precipitation from rain and snow in different parts of this country between 1870 and 1901 varied from 1 inch to 100 inches. The great agricultural area included in the central basin of the Mississippi River had a mean annual precipitation varying between 30 inches and 50 inches; the North Atlantic and Middle Atlantic States had from 40 to 50 inches; the South Atlantic and Gulf States from 50 to 60 inches; the Great Plains States from 15 to 30 inches; the Rocky Mountain States from 1 to 20 inches; while the annual precipitation of the Pacific States ranged from 10 inches in the extreme southwest to 100 inches in the extreme northwest. It has been stated under "Variation in water requirements," that the growth of 90 bushels of corn per acre requires approximately 15 inches of water; 75 bushels of oats, 12 inches; 300 bushels of potatoes, $6\frac{1}{4}$ inches; and 2 tons of clover hay, 9 inches. Comparing these figures with the normal annual precipitations of the principal agricultural areas, it will be seen that the moisture falling as rain or snow would in nearly every instance be sufficient to produce large yields of staple crops if it could all be held in the soil and utilized for plant growth. It will be recalled, however, that the different classes of soil can hold in the upper 4 feet only from 3 inches to $7\frac{1}{2}$ inches of water available for plant growth at any one time. On the other hand, over all the agricultural areas of highest precipitation the fall of moisture is very unevenly distributed throughout the year, and the larger quantities do not fall during the growing season. Because of this, large quantities of water drain away from the land, making it necessary in nearly every farm area to adopt means to prevent the escape of moisture from the soil.

Prevention of evaporation (Ref. No. 6, pp. 108–119; or No. 10, pp. 147–164).—The most effective preventive of loss of capillary water from soil is a dry surface which retards the movement of moisture through it. Probably everyone has tried the old experiment of making a path for a little stream of water by wetting a finger and drawing it along a gently inclined board and has been astonished to see how irregular a path the water can be made to follow by this means. This is because the film of water supplied by the wet finger offers less resistance to the movement of the remainder of the water than does the surface of the dry wood. In the same way moisture in the subsoil can pass upward by capillary action much more readily when the soil is moist than after it has been dried. A surface layer a few inches in depth of thoroughly dry soil practically prohibits the further capillary rise of water to the surface. Water does, of course,

continue to evaporate at the upper portion of the layer containing moisture, but the surface layer of dry soil keeps the moist soil below somewhat cooler, so that loss by evaporation is greatly lessened. A dry, loose layer of soil or other material is called a mulch. The development of a soil mulch is by all means the cheapest and usually the most effective way of reducing the water loss by evaporation. The common farm method of developing a soil mulch is by cultivation, which also kills weeds and promotes the circulation of air in the soil.

The loss of water from surface evaporation, other conditions being equal, is greater in fine-textured than in coarse-textured soils; likewise, the firmer the soil surface, the greater is the loss. This explains an objection to leaving a rolled surface in preparing a seed bed or after planting. Experimental results from cultivation to depths of 1, 2, and 3 inches, respectively, and at intervals of one-half, one, and two weeks have shown, in general, that within these limits the deeper the mulch and the more frequent the cultivation, the greater are the quantities of soil moisture preserved. A general average from these same results shows that a soil mulch prevents the evaporation of about 3,500 pounds of water per day over each acre of land, which is about one-tenth of the quantity required during three months of the growing season to produce a 90-bushel crop of corn. While these results vary considerably with climate, soil, and season, yet they are significant in showing the means of retaining moisture in the soil by cultivation.

The depth of mulch which is desirable depends on circumstances. Under most conditions a mulch of 3 inches has at least three-fourths the efficiency of a mulch of 5 or 6 inches in depth, and in the case of such crops as corn, in which the roots are apt to come close to the surface, so that cultivation to a depth of 5 or 6 inches would cut off many of them, it is unwise to attempt to produce a mulch more than 3 or 4 inches in depth. In many cases the cultivation of the soil from 2 to 3 inches in depth is to be preferred. Deep cultivation is generally undesirable in the Mississippi Valley and the eastern part of the United States. Farther west, where the rainfall is 25 inches or less annually, and the roots of plants are forced to grow deeper, a greater depth of mulch is considered desirable, and it is a common practice to cultivate to a depth of 5 or 6 inches.

Dry farming (Ref. No. 10).—Dry farming is a term which has come to be applied to the practice of agriculture in the arid lands of the West and Northwest. Where irrigation is impracticable, and where the annual rainfall is so low that it is impossible to grow a crop each year, land is fallowed every other year by keeping up a thorough cultivation which prevents the growth of vegetation and

keeps up a protective mulch over the surface. This mulch and the destruction of weeds largely prevent the loss of moisture from the soil and it is held for use by the crop of the following year.

Other means used to control the water supply of the soil are irrigation and drainage.

EXERCISES, LESSON IV.

Materials required.—One small balance or scales; four 1-pound baking-powder cans; 4 quarts each of dry sand, dry muck or peat, dry clay or silt loam; one 2-quart pail; a small piece of cloth; two cups; two or three pie tins; two or three small shallow dishes (saucers); a small quantity of lump and powdered sugar; six fine sewing needles; two pieces of $\frac{3}{4}$ or 1 inch glass tubing 2 feet long; one-half bushel of moist loam or silt loam; two 2-gallon crocks.

Water-holding capacity of soils (See reference in lesson).—Turn four 1-pound baking-powder cans upside down and punch three holes in the bottom of each. Obtain the weight of each can. Fill can No. 1 with dry sand, can No. 2 with dry muck or peat, can No. 3 with dry clay or silt loam, and can No. 4 with a mixture of one part (by volume) of dry sand and one part of dry muck or peat. Determine the weight of dry soil in each can. Saturate all with water, let stand until no more water drips from them, then weigh again. Determine the percentage of capillary water retained by each kind of soil. Account for the variation in water-holding capacity of the several samples. How may the water-holding capacity of a sand be increased? Of a heavy clay? Which class of soil will give up its water the easier, sand or clay? Why? On which soil do crops suffer more for want of water during a drought?

Percolation of water through soils (Ref. Nos. 2, pp. 170-173; 4, p. 32).—Punch a half-inch hole through the side and near the bottom of a 2-quart tin pail. Cover the opening on the inside with thin cloth and fill the pail with sand. Put a stopper in the opening and saturate the soil with water, measuring the quantity of water used. When saturated, remove the stopper and catch and measure the water that runs out. When dripping ceases compare the quantity of water caught with that used to saturate the soil. What name may be given to the water retained by the soil?

Capillary rise of soil water.—Pour a cupful of dry sand on a pie tin in a conical pile. Pour about a third of a cupful of water into the tin (not on the sand pile) and observe results. What name is given to this phenomenon? Of what importance is it in agriculture? Is this the only direction in which film water moves in the soil? What determines the direction of movement? In what kind of soil will water rise the higher, sand or clay? Explain. Repeat this experiment, if possible, by using 2-foot glass tubes filled with dry sand and clay loam. Cover the lower end of each tube with cloth, tamp the soil carefully, and stand tubes in a tray. Pour about half an inch of water into the tray and observe results. Note carefully the rate of rise and the height to which the water will rise in each tube.

Resistance of dry soil particles to water films.—Fill a small dish with water; place a perfectly dry, fine needle carefully on the surface film of the water. The needle will float. Explain. Take a pinch of road dust and let it drop carefully into the water. What happens to the finest dry particles? Explain. Why do water drops roll off a dusty board like so many shot?

Conserving soil moisture (Ref. No. 3, p. 264).—Sprinkle as much powdered sugar on top of a lump (do not press down the powdered sugar) as it will hold, and place the lump in a pool of about 12 drops of water poured out on a smooth surface. What happens? Explain fully. Let the lump of sugar represent a portion of soil immediately underneath a thoroughly cultivated surface. What does the powdered sugar represent? Is this principle of moisture conservation practiced in connection with all farm crops? Repeat the experiment using dry caked and powdered clay.

Obtain about 16 quarts of moist soil, mix well, and fill one 2-gallon crock within half an inch of the top, leaving the surface smooth and compact. In filling this crock tamp the soil gently so as to bring the soil particles in close contact with each other. Fill another crock in a similar manner within an inch and a half of the top. Cover this surface, which should not be too compact, with an inch and a half of loose dry soil. Place both crocks exposed to sun and circulating air. Do not water. After a week or 10 days take off the dust mulch in crock No. 2 and compare the moisture content of the soil beneath with the soil $1\frac{1}{2}$ inches beneath the surface of crock No. 1.

What precautions should be observed in frequent cultivation during a dry period? Is it possible to keep a heavy soil in good tillable condition if soil mulching is practiced? What should be done with the garden during dry seasons to conserve the water applied in the evenings? When should this be done? Why?

Field excursions.—Observations may be made concerning methods of cultivation, soil mulching, crop growth on low, wet lands, on gravelly knolls, etc.

REVIEW QUESTIONS, LESSON IV.

1. What is meant by water-holding capacity of a soil?
2. Distinguish between gravitational or drainage water and capillary water. Draw a diagram to illustrate how capillary water is held by the soil.
3. What is meant by the ground water table?
4. Explain the relation between texture and capillary water content of soils.
5. Why is the water-holding capacity of soils affected by the percentage of humus they contain?
6. Compare the quantity of water available for growing crops, a few days after heavy rains, in the depth of 4 feet of a silt loam and a very sandy soil.
7. Explain the cause of capillary rise of water in soils.
8. Explain fully the way in which evaporation of moisture from the soil may be lessened and state the principles underlying this method.
9. Why is it that a rainfall of 15 inches in the northern part of the United States is as effective for the growth of crops as one of 25 inches in the southern portion?
10. To what extent do you think that the moisture in the subsoil at a depth of 20 feet may be counted on for support in growing large crops? Discuss fully.

LESSON V. SOIL TEMPERATURE AND DRAINAGE.

SOIL TEMPERATURE.

(Ref. No. 2, pp. 218–238; or No. 3, pp. 289–294; 314–317; 325.)

It is a well-known fact that the soil must be comparatively warm before plants will grow. The limits of temperature for growth vary considerably for different farm crops, and there is some variation in the temperature necessary for the growth of any one crop in different latitudes. It has been found that, with other conditions favorable, staple crops will grow when the soil temperatures are as low as from 40° to 50° Fahrenheit, and as high as from 110° to 120° . The best growth ordinarily takes place at temperatures ranging from 65° to 70° . In the United States, especially in the northern half, the average soil temperatures for the growing season are considerably below these figures. Besides being necessary for the performance of the functions of growth in plants, certain temperatures are also essential in order that the chemical reactions and the microbiological activities furnishing available plant food may take place in the soil.

Factors influencing soil temperature.—The sun is the chief source of heat for the earth's surface. The sun's rays are conducted to the earth as light. These rays are transformed into heat and absorbed, or are largely reflected back into the atmosphere, depending upon the condition of the soil material which the rays reach. Dark soils transform and absorb as heat much more from the sun's rays than do light-colored soils. Besides the sun, an indirect source of a small amount of heat is the chemical and microbiological changes taking place in the soil. A chemical reaction usually produces heat, and microbiological activities frequently do.

The principal conditions affecting the temperature of the soil are: (1) Latitude. The farther north or south of the equator a land surface is the less direct are the sun's rays upon it and, other things being equal, the less will be the total heat absorbed in any given time. (2) Slope. A southern hillside will be warmer than the northern, because the sun's rays upon it are more direct. (3) Circulation of air above the soil. The varying temperature and humidity of the currents of air upon hillsides and in valleys have a considerable effect upon the temperature of the soil areas over which they pass. (4) Composition and texture of the soil. Both of these factors affect the conductivity of heat into the subsurface soil. Some rock materials are better conductors of heat than others. Again, air is a poor conductor of heat, and the greater the pore space in soil the less rapidly will heat be conducted through it. Fine-textured soils thus conduct heat less rapidly than coarse-textured soils of like composition. Clay soils warm up less quickly in spring than sandy soils which have less pore space. Peat soils formed in marshes are very open and spongelike, and this large air space causes heat to pass down into such soils with extreme slowness. Frost is often found in marshes several weeks after it has entirely disappeared in upland and more compact soils. (5) Water content of the soil. This has a very important influence upon the soil temperature. It takes nearly twice as much heat to raise water 1° in temperature as it does to raise the same weight of soil 1°. Then the evaporation of moisture from the surface of the soil uses up a great deal of heat and does much to keep the soil cold. It requires as much heat to evaporate a pound of water as would raise the temperature of a cubic foot of average soil over 10° Fahrenheit. (6) Color. Dark-colored soils, other conditions being equal, are warmer than light-colored.

There are at least four practical means by which the temperature of soil may be regulated: (1) By means of vegetable matter. A good supply of barnyard manure or green manure in the soil will have an appreciable effect in warming it. (2) By rolling. The heat conductivity

of soil can be much improved by rolling, especially when the surface is loose. By this means an additional amount of heat can be carried into the subsurface soil. At a depth of 3 inches rolling commonly warms the soil as much as 3° . If the surface soil is moist, however, the rolling should be followed at once by cultivation to prevent evaporation of moisture. (3) By use of a soil mulch. As has been stated above, the evaporation of moisture takes a great deal of heat from the soil. The soil mulch, by preventing evaporation, conserves much heat for the growth of crops. (4) By drainage. In well-drained soils the gravitational water is drawn off from beneath instead of evaporating from the surface. Soil that is tile drained is 5° to 10° warmer in the spring than it was before it was drained. The temperature of the soil in turn affects the temperature of the air in immediate contact with it, and frost often occurs on poorly drained soil at night where it does not form on well-drained soil.

DRAINAGE.

An excess of water prevents the entrance of the necessary air into the soil; it hinders the normal development of soil microorganisms; it leads to the puddling of clay soils and consequently produces poor tilth; it keeps the soil cold, especially in the spring; and, finally, it causes a leaching of plant-food substances from the soil.

Conditions where drainage is necessary (Ref. No. 8, pp. 14-16).—It is usually not difficult to detect the need of drainage. There are cases, however, when late in summer it is difficult to determine whether partial crop failure was caused by poor drainage earlier in the season or from the lack of necessary elements of plant food. Water should not stand on the surface of cultivated soils any longer than can be helped. Especially in the Northern States, where the growing season is short, it is desirable to have drainage in the spring as thorough as possible. Soil should not be saturated within 3 feet of the surface for most crops, though many grasses will make a very good growth on land which is saturated within 18 inches of the surface, or even nearer, for a portion of the growing season. Drainage is especially desirable in irregular fields where the drainage of wet portions will permit the laying out of a field of proper dimensions and also make it possible for the whole field to be tilled at one time. This not only increases the acreage of available land but greatly increases the efficiency with which operations of tillage and harvesting can be performed. Drainage in any case simply removes the gravitational water, and it is a mistake to think that good drainage is detrimental to crops, even in dry seasons.

It is customary to speak of surface and subsurface drainage, referring to the removal of surface or flood water in one case and to the withdrawal of the excess of water from the subsoil in the other.

Surface drainage (Ref. No. 8, pp. 7-9).—In the removal of surface water it is ordinarily necessary to use open ditches of sufficient size to carry the water coming to the drained land from adjacent territory. The size of the ditch necessary in such a case can be approximately estimated by observing the flow of water following a severe freshet. When the surface water from large areas is to be carried away it is best to secure the services of an engineer who, after making the necessary survey of the area to be drained, can compute the size of the ditch necessary.

In the case of comparatively level land, where it is impossible to establish an outlet for subsurface drainage, surface drainage should be made as effective as possible. This is especially necessary where the land is underlain by an impervious clay subsoil. It is often practical to use the common plow in ditching such level areas. The plowing should be done in long narrow lands, and the dead furrows should be carefully cleaned out to serve as drainage ditches. It is frequently necessary to cut ditches across from one dead furrow to another in order to drain a slight depression which would otherwise be filled with water. These narrow plow lands should usually be kept in the same position for two or three years in order to round up the back furrow somewhat and deepen the dead furrow, but they can not be kept longer than three years ordinarily without widening the dead furrow to an undesirable extent. After this the plowing must be reversed, and the first two furrows of the lands turned into the dead furrows. This method of surface drainage has its greatest objection, perhaps, in the difficulty which comes from working over the open-furrow ditches.

The timely use of a shovel or large hoe in the spring will greatly aid in removing the surface water coming from rain and melting snow.

Subsurface or underdrainage (Ref. No. 8, pp. 27-34).—Practically all underdrainage is now accomplished through the use of common porous clay tile or glazed tile, laid loose jointed so that the water may pass into the drains through the joints or where the tile meet. The glazed tile are usually more expensive than the porous, but they are also more durable. Factors of greatest importance to be determined in planning an underdrainage system are (1) depth at which the tile should be placed, (2) the available fall or grade of the tile, (3) the system to be used, (4) the distance apart of tile lines or laterals, and (5) the size of tile to be used.

Depth.—The depth for placing tile is dependent upon several things. First of all, tile must always be placed below the depth of tillage and also below the frost line. Freezing will crumble porous tile, and it causes heaving of the ground and displacement of the tile in any case. The depth to which tile should be placed varies also with the type of soil and the desired depth of water table. The

movement of water in silt loam, clay loam, and clay soils is essentially all through granulation spaces, as very little takes place between the finest soil grains. In such soils tile must not be placed much below the level to which granulation extends. This usually means about 3 to 3½ feet. Occasionally it is necessary for short distances to place tile much deeper in order to keep the necessary grade.

Grade.—The difference of levels between the outlet and the highest point of the drainage system divided by the distance between these positions naturally establishes the maximum grade possible. Where the fall is slight the minimum grade permissible for effective drainage depends largely upon the length of the drain and the size of the tile. Water will flow more rapidly in large tile having a given gradient than in small tile. Lateral or branch tile having a diameter of 3 or 4 inches may be laid with as little fall as 1 inch to 100 feet for several hundred feet in length, provided the soil is of a clayey nature. If laid in fine sandy soils, so that there is danger of the sand finding entrance to the tile through joints, the grade must be not less than 3 or 4 inches per 100 feet, in order that the current in the tile may be sufficient to keep it clean. Soil may often be kept from passing into the tile by placing straw or other similar material over the joints before covering the tile.

System (Ref. No. 8, pp. 38–43).—By “drainage system” is meant the arrangement of the lines of tile which are to collect the surplus waters from any piece of land. There are several of these systems. The one which should be used in any case will depend upon the shape, the size, and the surface topography of the area to be drained. In many instances two or more of these systems may be effectively combined.

Distance apart of laterals.—When wet lands are in the form of narrow runs or sloughs, tile ditches should be dug as nearly as practicable along the courses in which the water naturally runs, although it is frequently necessary to straighten these considerably. When broader areas are being drained, so that laterals or side branches of tile are necessary, the distance between these will be determined by the degree of drainage to be secured and by the character of the soil. In the case of fine-textured clay soils it is necessary to put tile drains as close as 2 rods apart in order to secure the thorough drainage necessary for garden or truck crops, though laterals placed 4 rods apart should give sufficient drainage for practically all staple crops. In wet sandy soils the laterals may be placed farther apart, though, as mentioned above, they must be of sufficient size to remove the water freely.

Size of tile (Ref. No. 8, p. 82).—In determining the sizes of lateral and of main tile to use under different conditions, certain principles

should be kept in mind. The quantity of water carried by any pipe or carrier of drainage is equal to the area of the cross section of the stream multiplied by its rate of flow. This rate of flow in a tile line will vary with the fall, the length of line, the size of tile, and the degree of smoothness of the inside of the tile. It is well to keep in mind that the cross sectional area of a tile varies directly as the square of its diameter. This means that, other things being equal, a 6-inch tile has about four times the water-carrying capacity of a 3-inch tile. It should also be kept in mind in this connection that the cost of tile does not increase in proportion to size. That is to say, 6-inch tile does not cost twice as much as 3-inch tile. Frequently 4-inch tile can be bought as cheap, or nearly so, as 3-inch, although their water-carrying capacity is nearly double that of the 3-inch. Again, the cost of digging the ditch and laying the tile, which is commonly of greatest consideration, is practically independent of the size of the tile to be laid. It is always best to be on the safe side with regard to the size of tile purchased for any drainage system. An estimate of the size of tile necessary for fields of different dimensions is given by Elliott (Ref. No. 8, p. 84).

Where the size of tile, or anything else in connection with drainage, is difficult to determine, it is advisable to consult the State agricultural college or a drainage engineer.

Laying out the drainage system.—After the lines along which tile are to be laid have been staked out by the use of laths or other stakes 2 to 3 feet in length, placed 50 feet apart, short stakes, called grade stakes, should be driven even with the surface of the ground near the lath. (Ref. No. 8, pp. 48, 63–65.) A line of levels should then be run along the grade stakes, beginning with the lower end at the level of the outlet. In recording the levels this first stake should be numbered zero (0). (Ref. No. 8, pp. 58–63.) By determining the difference in height between each succeeding pair of stakes the line of elevation of the surface of the ground is determined and may be platted on horizontally ruled paper. When this line of elevation has been drawn the fall available can be determined.

The next item to be found is the grade which can be used. (Ref. No. 8, pp. 68–74.) To do this, subtract the distance which the tile must be placed below the surface at the upper end, or at the point where the tile comes nearest to the surface, from the total height of the surface at that point above the outlet. This gives the fall which may be used by the tile through this distance. Ordinarily the gradient should be uniform, but where laterals join larger mains it is possible to use smaller gradients on the mains than are used on the laterals. Having determined the total fall in inches or hundredths of feet, divide this by the number of hundred feet in the length of tile to get the fall per hundred feet. Half of this will be the difference in

level of the bottom of the ditch between the stakes which are 50 feet apart.

The height of the bottom of the ditch or the grade line, above the outlet can now be determined for each grade stake. These heights should be written in a column opposite the elevations of the surface of the ground. By subtracting the elevation of the grade line from that of the surface of the ground, the depth of cut can be found at each stake. These depths can be written in proper order in a third column.

The construction of the ditch may now be undertaken. (Ref. No. 8, pp. 89-98.) This should be started at the lower end, or outlet. It is necessary now to have a method of determining exactly when the grade line or bottom of the ditch is reached. To do this, place strong stakes at each of the two lower stakes with a line between. This line is to be placed at a uniform height above the bottom of the finished ditch. A string may be adjusted at a convenient height of 5 or 6 feet above the bottom of the ditch by subtracting the depth of digging at each stake from the 5 or 6 feet decided on and measuring up from the surface of the ground this distance on the stake. Fastening the string at this point for each of the two stakes will bring the string exactly parallel with the bottom of the ditch and 5 or 6 feet above it.

Digging the ditch and completing the drain.—The tools necessary include a ditching spade with a blade about 8 inches wide, slightly curved, and square at the cutting edge; a long-handled pointed shovel; a tile scoop; and, if much tile is to be laid, a tile hook. A strong string is first stretched along the edge of the ditch to keep it straight. Digging begins at the lower end and proceeds upgrade in sections, removing the dirt to a spade depth at a time. The width of the ditch will depend on the depth but should be no greater than is absolutely necessary. Care must be taken not to remove dirt below the grade line. When the grade line is nearly reached over a distance of 6 or 8 feet the last thin layer of dirt is removed with the tile scoop, which produces a straight, smooth bottom on which the tile may be placed. Tile may be placed by hand, though if the ditch is deep and much is to be laid the tile hook will permit much more rapid and easy work. The tile should be placed so that they fit closely together end to end, and care must be taken whenever work is left for the night to have the upper end protected by a flat stone or otherwise so that much soil may not be washed in in case of rain. The tile should be covered immediately after laying to a depth of 2 or 3 inches after heavy soil or other material has been used over joints to prevent sand or other loose material from working into the tile. (Ref. No. 8, p. 99.) This is called blinding. The remainder

of the filling may sometimes be done quickly and efficiently with a team and scraper.

Cost and profits of drainage.—The final questions which are always considered in connection with any needed drainage are (1) the cost, and (2) whether the accruing profits from increased production will warrant the cost of putting in the drainage system. The conditions which determine these two factors are so varied that no discussion of the matter will be entered into in this lesson. The different items of cost and profit are separately considered by Elliott (Ref. No. 8, pp. 121–138) and should be carefully studied by those who contemplate carrying out a drainage project.

Drainage of irrigated and alkali lands.—It frequently happens in arid lands where irrigation is practiced that soil areas which are adjacent to or somewhat below the level of irrigation canals or irrigated fields, and which have been fertile and productive for years, finally become unproductive and practically useless for agricultural purposes. Investigation has shown that almost invariably the changed condition is due to the subsurface soil being water-soaked from seepage from irrigated areas or irrigation canals or from excessive use of irrigation water. These areas are often at considerable distances from the source of the trouble. Where such a condition exists the surface soil also frequently becomes laden with soluble salts which are harmful to the crops commonly grown upon the land. This is because the seepage and other waters have carried quantities of these salts in solution which later become deposited at the surface of the soil upon the evaporation of the salt solution. Such deposits of salts, including sulphate, chlorid, and carbonates of sodium, magnesium sulphate (epsom salts), calcium sulphate (gypsum), and calcium chlorid, are also commonly found in spots of the surface area of extremely arid lands not irrigated. This is because the rise of water from capillarity, leaving the salts deposited upon evaporation, exceeds the downward movements from the rainfall. Areas containing harmful quantities of soluble salts in the surface soil are called alkali lands. If sodium carbonate is present in considerable quantity the alkali is usually dark colored due to action of the alkali on organic matter and is known as black alkali. The sodium carbonate, besides being harmful to plant growth, often causes the soil particles to puddle and to form an impenetrable hardpan a few inches below the surface of the soil. White alkali is that in which sodium sulphate and similar neutral salts which do not blacken organic matter predominate. This is much less harmful than black alkali. Underdrainage is one of the best ways of preventing the accumulation of alkali in soils and of reclaiming watersoaked and seeped areas, it being frequently established as a

the excess of soluble salts to percolate through the soil and pass away in the drains. Where alkali spots occur in arid lands the most effective and certain relief is usually afforded by underdrainage combined with surface flooding. The few rains which occur in these places, or a flooding of the land where possible, will finally carry the excess of harmful soluble salts from the surface soils into the drains. Calcium sulphate (gypsum) is very advantageously applied to black alkali lands before flooding. This results in a chemical reaction yielding calcium carbonate and sodium sulphate, which is much less harmful than sodium carbonate and is readily removed by drainage.

The methods of underdrainage of irrigated and alkali lands differ from those used in humid sections.

EXERCISES, LESSON V.

Materials required.—Four boxes 1 foot square and 4 inches deep; a sufficient quantity of clay or silt loam to fill these boxes; a few small thermometers; three 3-inch unglazed tile; two tight wooden boxes 10 by 12 by 10 inches; a small quantity of paraffin or paint; paper, pencil, and ruler.

Influence of slope (Ref. Nos. 2, pp. 228, 229; 3, pp. 458, 459).—Fill two boxes, each 1 foot square and 4 inches deep, level full of the same kind of soil. Have the soil equally compact in both boxes. Place both boxes in the sunlight, so that the surface of the soil in one box will be at right angles to the rays, and in the other nearly parallel with the rays. After an hour or two compare the temperature of the two soils. Explain the differences. What are the advantages of a north slope as a site for an orchard?

Influence of water content.—Fill two boxes as in the preceding exercise with almost dry clay or silt loam. Compact soil equally in both boxes. Wet the soil in one box almost to saturation with water. The water used should be of the same temperature as the soil in the other box. Take the temperature of the soil in both boxes, then place them in the sun. After two or three hours compare the temperature of the soil in the two boxes. Which requires more heat to raise 100 pounds 1°, water or dry soil? Why should a low, wet soil be called a cold soil?

How tile works (Ref. No. 8, p. 28).—Secure three 3-inch unglazed tile and two tight wooden boxes about 10 by 12 by 10 inches. Cut two holes in opposite sides near the bottom of one and on opposite ends near the bottom of the other box large enough to allow the tile to enter. Place one tile in the first box so that the two ends will project from either side. Place the other two tile end to end with the joint in the middle of the box and the ends of the tile projecting from either end of the box. Make both boxes water-tight by means of paraffin or paint (do not seal the joint of the tile in the box containing the two tile), and fill each box with sandy soil. Saturate the soil with water and note results. Explain fully how tile works under field conditions. Are there any objections to glazed tile?

Two drainage systems.—A level field 80 rods long and 20 rods wide has a ditch 6 feet deep across one end. Draw out to scale of 5 rods to 1 inch two systems for laying out drains, namely, one with a long main and short laterals, and the other with a short main and long laterals. Place the laterals in each case 4 rods apart.

Compare the number of rods of tile required for the two systems. Make computations from the drawings.

Principles of tile laying (Ref. No. 8, pp. 63–68).—An outlet ditch 6 feet wide at the bottom, 7 feet deep, and 20 feet wide at the top has a line of tile emptying into it 4 feet

below the grade stake No. 0 at the top of the ditch. The elevations above datum plane at the grade stakes are as follows: No. 0, 52 feet; No. 1, 52 feet; No. 2, 52.5 feet; No. 3, 52.75 feet; No. 4, 53.25 feet; No. 5, 54.25 feet; No. 6, 53.75 feet; No. 7, 54 feet; No. 8, 54 feet; No. 9, 54 feet; and No. 10, 53 feet.

(a) Draw a profile or cross section of the ditch and ground, showing the line of elevation of the surface of the ground. Use ruled paper having lines drawn $\frac{1}{4}$ inch apart each way. Let each $\frac{1}{4}$ inch on the horizontal lines represent 25 feet, and each $\frac{1}{4}$ inch on the vertical lines represent 2 feet.

(b) At grade stake No. 10 the tile was laid $3\frac{3}{4}$ feet deep. Determine the fall that was available. This line of tile was laid with a uniform gradient. Determine the fall in inches per hundred feet.

(c) Determine the grade line, or the height of the bottom of the ditch above the outlet at each grade stake. (Ref. No. 8, pp. 72-74.) Set these elevations down in a column opposite the elevations of the surface of the ground at each grade stake.

(d) Determine the depth of cut that was made at each grade stake. (Ref. No. 8, pp. 77-82.)

(e) On the profile map draw a line 5 feet above and parallel with the grade line from stations No. 0 to station No. 10. Let this line represent the line of sight formed by the string to aid in the construction of the ditch. (See p. 37.) Determine the height the string should be above each grade stake.

Field excursions.—(a) By the use of any convenient thermometer, the temperature of various soils may be compared; north slopes with south slopes, black and light colored soils, upland and lowland, drained and undrained lowland, sandy soil and clay or silt loam, loose and compact clay or silt loam. Explain all variations found.

(b) If convenient, make a trip to inspect some drainage systems. Make a sketch of the drained area and draw in the drainage system.

If convenient, in the spring compare the temperature of the soil above a line of tile with that midway between laterals.

Observe the natural drainage of any interesting area.

REVIEW QUESTIONS, LESSON V.

1. How is soil temperature related to fertility and the growth of crops?
2. Explain fully what becomes of the heat which is absorbed by the surface of the soil.
3. What factors influence the amount of heat which penetrates the subsoil?
4. Explain why frosts sometimes occur on poorly drained ground when they do not occur on well-drained ground?
5. Discuss the practical means of regulating soil temperature.
6. State several benefits which may be derived by good drainage of soils.
7. How can you tell whether the soil of a given field is well drained or not?
8. Describe a good method for the surface drainage of flat land which is nearly level.
9. Why is underdrainage by the use of tile more to be desired than surface drainage?
10. How does the water from the surface find its way into lines of tile?
11. What kind of soil is most difficult to drain by means of tile?
12. Estimate the slope in feet per mile necessary to permit good tile drainage on an 80-acre field?
13. What should the diameter of a main outlet of tile be on a field of 100 acres having a slope of 1 inch to 100 feet?
14. Define grade stakes, line of levels, grade line.
15. How should tile be laid? What is meant by blinding tile?

LESSON VI. THE NITROGEN SUPPLY OF THE SOIL.

(Ref. No. 2, pp. 110-119.)

As stated in Lesson II, nitrogen is one of the most important elements of plant growth. Nearly four-fifths of the atmosphere, or over 70,000,000 pounds over each acre of land, is nitrogen. While this is sufficient to support plant growth for thousands of years, yet atmospheric nitrogen can not be utilized directly in plant growth but must first be combined in the soil with other elements before plants can absorb it. It will be the purpose of this lesson to explain how the nitrogen of the air becomes transformed so as to be used by plants and to discuss briefly the practical means of maintaining the soil-nitrogen supply.

Combined nitrogen in the atmosphere (Ref. No. 1, p. 22).—From the decay of vegetable and animal materials, burning, electrical discharges, and other causes the atmosphere derives certain substances, among which are ammonia and nitric acid, both compounds of nitrogen. These gases are readily absorbed by the moisture of the atmosphere, and when this moisture condenses and falls as rain or snow it carries with it into the soil the nitrogen compounds which it contains. While the available nitrogen thus added to the soil is not large, yet it is an appreciable quantity and contributes in a small way to the soil's fertility.

The fixation of atmospheric nitrogen in the soil (Ref. No. 7, pp. 213-223).—The nitrogen of the soil which plants require comes ultimately from the atmosphere. A large supply of this nitrogen is collected from the atmosphere in the soil through the action of microorganisms called bacteria. The nitrogen-fixing bacteria of the soil may be divided into two classes. One class lives independently in the soil and secures nitrogen direct from the air for its growth. After these bacteria perform their life's work their bodies decompose and the combined nitrogen which they contain becomes available for the growth of plants. The amount of nitrogen fixed by this class of bacteria in ordinary cultivated soils has been estimated by different investigators at from 15 to 40 pounds per acre. Probably the latter figure is much above the general average, even under favorable conditions. The other class of nitrogen-fixing bacteria lives in connection with the roots of certain plants, viz, of the family of legumes, including clovers, alfalfa, beans, peas, and others. These bacteria form nodules or tubercles in which the chemical combination of nitrogen with other elements takes place and from which the host plant obtains much of its nitrogen for growth.

Inoculation (Ref. No. 7, pp. 223-228).—The bacteria which form tubercles on the roots of leguminous plants are generally different for different species of plants. Those which live on alfalfa, however, are

the same as those which live on sweet clover, and the nodule bacteria of the true clovers have also been found to be interchangeable for purposes of inoculation. The bacteria of cowpeas and soy beans are not interchangeable nor can they be used for inoculating any other of the leguminous plants. It often happens in a particular field that bacteria of the right kind are not present to form nodules on a species of legume which is being grown on the field for the first time. It is then necessary to supply these bacteria. This is done in two different ways:

(1) A culture of bacteria is used. This culture is made by transferring some bacteria from a plant nodule to a substance suitable for their growth. Under right conditions of temperature and air these bacteria multiply very rapidly, and in a comparatively short time the growing medium will contain millions of the microorganisms and is then called a culture. This culture growth of nodule bacteria needs to be handled by trained people in order that it may be kept pure. The United States Department of Agriculture, several of the State agricultural experiment stations, and many commercial firms have been growing cultures for agricultural use. These cultures, with directions for their use, are shipped direct to farmers by express or parcel post. The cultures are most commonly applied to seeds just before sowing. The methods are very simple and easy to carry out.

(2) Soil is used for inoculation. Soil to be used for this purpose should be taken from a field in which are growing, or have recently grown, healthy plants containing a good supply of the nodule bacteria desired. Nodules occur largely in the surface soil, ordinarily in the first 5 or 6 inches. In securing soil for inoculating, the first inch or so should be scraped away and the soil to the next few inches of depth should be taken. From 200 to 400 pounds per acre of inoculated soil can be scattered over a field before sowing and harrowed in, or the soil containing bacteria can be stirred up in water and after settling the liquid can be poured off and used to inoculate seeds much as the cultures are used. With either method of inoculation care must be taken not to permit too intense heat from the sun to kill the bacteria. This can be avoided by harrowing under the seeds or soil-carrying inoculation soon after sowing them, or by doing the work early in the morning or late in the afternoon.

Amount of nitrogen fixed in the soil by legumes.—The fixation of nitrogen through the action of tubercle-forming organisms growing on the roots of legumes is the only practical method available to the farmer for storing this essential element in the soil. It must not be supposed, however, that all the nitrogen used by leguminous plants in their growth is secured in this way from the nitrogen of the soil air. Soluble nitrates of the soil are absorbed by growing clover and alfalfa, for example, just as they are by corn and cotton. But while

corn, cotton, and other nonlegumes secure all of the nitrogen from the soil for their growth, clovers, alfalfa, and other legumes secure a substantial part of their nitrogen by fixation from the air. Since there is always under field conditions a larger or smaller amount of nitrogen compounds made available to legumes, it is extremely difficult to determine just how much is fixed from the air. Under conditions of average fertility it is probable that about one-third of the nitrogen used by clover or alfalfa is taken direct from the soil, while about two-thirds is secured from the nitrogen of the air in the soil. When these crops are cut for hay, about one-third of the total amount of the nitrogen contained in the entire plant is left in the roots and stubble and about two-thirds is removed in the hay. Figuring from the above estimates, when a crop of clover or alfalfa is removed from the land the soil is left with practically the same amount of nitrogen that it had before the crop was grown. This, however, does not take into account what is lost by leaching. Cow-peas, soy beans, and other legumes restore to the soil from roots and stems a somewhat smaller percentage of nitrogen than do the clovers and alfalfa. When leguminous crops, therefore, are sold from the farm there results at least no gain of nitrogen to the soil. On the other hand, if these crops are fed to stock and the manure produced returned to the land, much of the nitrogen contained in the crops will go back to the soil and an actual increase of the nitrogen content of the farm will result. But when only corn and other grains or hay from timothy and other nonlegumes are grown, there results a positive gradual loss in the nitrogen content of the soil, no matter what may be the disposition of the crops.

Nitrification (Ref. No. 4, pp. 135-140).—Nitrogen is used for growth by plants in the form of chemical compounds called ammonia and nitrates. It is now known that rice takes up ammonia directly, while, as far as is known, all other farm crops absorb nitrogen chiefly in the form of nitrates. Organic matter can not, therefore, be utilized for plant growth until it has first undergone a process of decomposition. This decomposition is caused by microorganisms, or bacteria, living in the soil, which use the organic matter, mostly vegetable, for their nourishment and produce as by-products ammonia and nitrates, which can then be absorbed by plants. The normal process of decomposition of organic matter and the formation of nitrates through bacterial action is called *nitrification*. These organisms perform their work only under favorable conditions of moisture, aeration, and temperature. Nitrification is twice as rapid at 70° as it is at 50° and twice as rapid at 90° as it is at 70°, but the maximum temperature is probably between 95° and 100°, and if a much higher temperature is reached the bacteria do not grow well. If the soil is poorly aerated and water-soaked from a lack of proper drainage, an

abnormal decomposition takes place, through bacterial action, resulting in a loss of free nitrogen from the soil. Such an abnormal decomposition is called *denitrification*. An acid condition of the soil is unfavorable, also, to nitrification. The farmer should recognize that suitable conditions must be provided for normal bacterial growth in the soil if good crops are to be expected.

Commercial materials containing nitrogen (Ref. No. 1, pp. 190-196; or No. 7, pp. 244-260).—Besides the natural methods discussed above of keeping up the nitrogen supply of the soil, there are many commercial products on the market which are used to a considerable extent for certain soils and crops. These include mineral salts, together with waste products of both animal and vegetable origin. The principal mineral salts of nitrogen used on soils are sodium nitrate and ammonium sulphate, together with calcium cyanamid and calcium nitrate, which have recently been manufactured from atmospheric nitrogen.

Cottonseed meal is the principal organic source of nitrogen used as a fertilizer in the United States. In fact, it is used to a larger extent in this country than any other kind of nitrogenous fertilizer, notwithstanding the fact that it is also a valuable stock food for which the demand is steadily increasing.

The commercial animal products used as fertilizer include slaughterhouse refuse, especially dried blood and tankage; fish not valuable for human food, which has been prepared for use as fertilizer by cooking and extraction of oil; bird guanos; and stockyard manure. Peruvian guano formed from the excrement of birds deposited in large quantities on islands off the coast of Peru is rich in nitrogen and was once extensively used in this country, but the original deposits are now so nearly exhausted that there is little or none of the material available for export.

Of the mineral nitrogen salts, ammonium sulphate is used to a considerable extent in this country. Its long-continued use has been found to produce unfavorable soil conditions, which, however, are easily corrected by applications of lime. A mineral material largely used to supply nitrogen to soils is sodium nitrate or Chile saltpeter, so-called because it is obtained mainly from the nitrate deposits of Chile. The great advantage of sodium nitrate as a plant food is that it is readily soluble in water and quickly becomes available to growing crops. When applied to a poor soil its effect can usually be quickly seen in the rapid growth and the rich green color which the plants take on. A disadvantage in the use of this material is its tendency to leach from the soil, as noted in a previous lesson. Sodium nitrate, and other products rich in nitrogen as well, must be applied to the soil with much knowledge and skill if they are to prove profitable. Usually from 100 to 200 pounds per acre of the nitrate is used, and

it is often well to make an application at a time when the crop is in especial need of help or stimulation in its growth.

Need of decaying vegetable matter in the soil.—Doubtless one of the greatest needs of the soils of the United States is more nitrogen through the growth of leguminous crops. This is especially true in the South, where long summers and much sandy soil cause the vegetable matter quickly to become depleted. Growing legumes for green manure, or, preferably, feeding the legumes and returning the manure to the soil, are the cheapest and most effective ways of supplying nitrogen for staple crops. Other advantages which green manure or barnyard manure have over commercial nitrogenous substances in the soil are: (1) They do much to maintain the moisture content; (2) they improve the texture; (3) they increase the temperature; and (4) they promote bacterial action. These advantages should never be overlooked in farm practice. Some of these benefits to the soil from decaying vegetable matter have been mentioned in previous lessons, but they will bear repetition.

EXERCISES, LESSON VI.

Materials required.—Four boxes; some poor, sandy soil; a few peas, oats, or grains of corn; sodium nitrate, ammonium sulphate, and pulverized limestone.

Leguminous plants.—If conditions permit, carefully dig up different species of leguminous plants and examine the roots for nodules. If plants are carelessly removed from the ground the nodules will be pulled off and remain in the soil. If plants are taken up with a spade or shovel so that considerable earth remains on the roots, and then if the soil be very carefully washed away, an examination of the fine roots will show the nodules. These will vary on different legumes from the size of a pinhead to that of a small pea, or even larger. If plants can not be dug out of doors, peas or beans planted in a box and kept growing well will show the nodules after a few weeks.

Inoculation.—It will be found interesting as a field test to sow two strips side by side of some leguminous plant not commonly grown in the community, inoculating the seed used for sowing one strip and sowing the other strip from uninoculated seed. Cultures for inoculation may be secured by applying to your State experiment station or to the United States Department of Agriculture, Washington, D. C. After growing some six weeks the roots of plants from the two plats should be carefully examined for nodules. After two or three months of growth note whether there is a difference in the growth of plants on the two plats.

Salts containing nitrogen.—Fill four boxes with poor sand. Plant either peas, oats, or corn in all four boxes. Keep warm and moist until the seeds are up. Mix into the soil of one box a good sprinkling of sodium nitrate; mix a like quantity of ammonium sulphate into the soil of the second box, and ammonium sulphate and powdered limestone into the soil of the third; leave the fourth box undisturbed. Keep all the plants in good condition for growth and watch for a few weeks. Note results.

PROBLEMS.

1. A 30-bushel wheat crop removes from 1 acre about 48 pounds of nitrogen; a 50-bushel oat crop removes about 50 pounds; and a 65-bushel corn crop removes about 85 pounds of nitrogen per acre. How many pounds of nitrogen are removed from the soil on a grain farm where 30 acres of wheat are raised averaging 20 bushels per

acre, 25 acres of oats averaging 40 bushels per acre, and 50 acres of corn yielding 52 bushels of shelled corn per acre?

2. A clay or silt loam soil weighs in round numbers 2,000,000 pounds per acre, 8 inches deep. How many pounds of nitrogen are contained in an acre 8 inches deep of a fertile clay loam that analyzes 0.25 per cent of nitrogen? (a) How many 65-bushel corn crops will the nitrogen contained in an acre of this soil supply?

3. An acre of sand 8 inches deep weighs, in round numbers, 2,500,000 pounds. What is the nitrogen content of an acre of poor sand that analyzes 0.04 per cent nitrogen?

4. An acre of peat soil 8 inches deep weighs, in round numbers, 350,000 pounds. How many pounds of nitrogen are contained in an acre 8 inches deep of a soil of this kind that analyzes $2\frac{1}{2}$ per cent nitrogen?

5. A certain silt loam contains 0.2 per cent nitrogen and a peat 3 per cent. In comparing these percentages, how many times more nitrogen are contained in the peat than in the silt loam?

(a) In comparing the actual number of pounds per acre 8 inches, how many times more nitrogen does the peat contain than the silt loam? Why this difference?

6. One ton of red-clover hay contains about 40 pounds of nitrogen, and 1 ton of alfalfa hay contains about 50 pounds. How many pounds of nitrogen are contained in 30 acres of clover yielding 2 tons per acre and 20 acres of alfalfa averaging $5\frac{1}{2}$ tons per acre from three cuttings?

(a) How many pounds of nitrogen can reasonably be assumed to have been fixed from the air by these two crops?

(b) At 15 cents per pound what is the value of the nitrogen contained in 5 tons of alfalfa hay?

(c) Wheat bran contains 2.5 per cent nitrogen. How much bran is equivalent to 1 ton of alfalfa in nitrogen content?

7. How many square inches of air over 1 acre?

8. Atmospheric pressure averages about 15 pounds per square inch. How many tons of air over 1 acre?

9. About four-fifths of the atmosphere consists of nitrogen. How many tons of nitrogen over 1 acre? Do you think legumes will ever run short of this element in their work of nitrogen fixation?

REVIEW QUESTIONS, LESSON VI.

1. Discuss fully the fixation of nitrogen in the soil by nodule bacteria.

2. Name some leguminous plants. In what particulars, from the standpoint of soil fertility, do they differ from nonleguminous plants?

3. Explain what is meant by inoculation of soils.

4. What conditions affect the amount of nitrogen fixed by legumes?

5. About how much nitrogen is fixed by a 2-ton clover crop?

6. Explain fully how legumes may be made of most use in increasing the amount of nitrogen in the soil of a farm.

7. What is meant by nitrification, and how does it differ from nitrogen fixation?

8. Name some of the commercial materials used to increase the nitrogen content of the soil.

9. Compare the value of these commercial materials with the products of vegetable decay in general farm practice.

10. Is all vegetable matter in soils helpful in supplying fertility? Explain.

11. May soils be considered inexhaustible in fertility?

12. Explain fully why a given soil may produce a large growth of native vegetation while the same soil after being brought under cultivation may fail to produce a large yield if the crops are removed from the land each year.

LESSON VII. THE PHOSPHORUS AND POTASSIUM OF SOILS.

The mineral elements of plant food in the soil which are most apt to be so low as to limit crop production are phosphorus and potassium (see p. 11). These elements, it will be remembered, come from the disintegration of rock materials. The total phosphorus and potassium content of a soil, therefore, depends primarily upon the kind of rocks from which the soil was formed. On the other hand, the quantity of phosphorus or potassium available to plants is not accurately measured by the total quantity of these elements in the soil, but depends much upon soil management. A soil may be rich in total phosphorus and potassium and yet crops may not be able to secure sufficient of these elements for large yields. The quantity of decaying vegetable matter in the soil has much to do with the quantity of mineral elements available to plants, but if a soil is low in phosphorus or potassium, or if the system of farming is such as to draw heavily upon these elements, materials rich in available phosphorus and potassium compounds may be added.

Any material which adds to the fertility of the soil is a fertilizer. This term, however, is more commonly applied to commercial materials used for this purpose, especially when the product contains two or more of the essential elements of plant growth. The phosphorus content of fertilizers is commonly expressed in textbooks and fertilizer analyses as phosphoric acid and the potassium content as potash. To think in terms of phosphorus, the compound phosphoric acid may be reduced to phosphorus by multiplying by 0.4366; potash may be reduced to the element potassium by multiplying by 0.83.

Phosphorus in the soil (Ref. No. 5, pp. 183, 184).—The proportion of this element in the most common soils of the United States is very small. The total amount on the average is from 0.05 per cent to 0.1 per cent. In many cases it is as low as 0.02 or 0.03 per cent. Since the soil of the surface, 8 inches, in which most of the organic matter occurs, weighs about 2,000,000 pounds on an acre, this means that there are normally between 400 to 2,000 pounds of phosphorus per acre, which constitutes most of the supply which can be made available to crops. Agricultural crops on the average take from 8 to 10 pounds of phosphorus per acre annually. The total supply of phosphorus in the soil to the depth of 8 inches would be, on this basis, sufficient to meet the needs of crops for from 50 to 250 years. This period would be much shorter in case of low phosphorus content or larger yields. Of course, it is probable that some of the phosphorus in the soil below a depth of 8 inches can be drawn on, but even if we assume that a considerable amount comes from below 8 inches, it is still evident that if the phosphorus absorbed from the

soil by crops grown on it is continually removed from the farm by the sale of crops, the supply will become depleted and phosphorus will become the limiting factor in crop production. In many instances this is now the case.

Phosphorus taken from the soil.—Most of the phosphorus absorbed by plants in their growth goes to the seed, so that when grain or seed is sold much of this element is removed from the soil. Likewise, when crops are fed to animals much of the phosphorus goes into the bones and milk, and if the animals or milk are sold from the farm considerable phosphorus is lost. It is evident also that the amount of phosphorus sold from the farm will vary greatly with the type of farming practiced. Grain raising is most apt to deplete the supply of phosphorus, since large quantities of this element are removed in the seed. The handling of live stock, especially if young animals born on the farm are raised and sold when they reach maturity, also removes considerable phosphorus. Dairy farming, in which it is customary to use a good deal of feed brought from outside of the farm and to sell butter fat which contains only a small amount of this element, removes much less; but even in dairy farming it must be recognized that there is some loss in the bones of old cows and in the milk, as well as by unavoidable leaching in the manure. In practice, these losses can be made good only by the purchase of phosphorus-bearing materials or of feeding stuffs which contain this element.

PHOSPHORUS-BEARING MATERIALS.

(Ref. No. 1, pp. 201-208; or No. 3, pp. 511-518; or No. 5, pp. 183-193; or No. 7, pp. 261-277.)

Besides what is naturally in the soil, the principal phosphorus-bearing materials are, (1) the bones of animals, (2) natural beds of calcium phosphate, and (3) phosphatic iron ores.

Bone phosphates.—A very limited supply of phosphorus for soil improvement comes from the bone meal prepared by packing houses. This, of course, comes originally from the soil. Raw bone contains from 9 to 11 per cent of phosphorus, but in preparing it for use on soils it is now usually steamed or otherwise treated to remove the bulk of the organic matter, and then ground. Steamed bone meal contains from 12 to 14 per cent of the element phosphorus. Sulphuric acid is sometimes added to bone meal. The resulting acidulated bone phosphate or so-called dissolved bone is more readily available than the raw bone. This product contains about 7 per cent of phosphorus and 2 per cent of nitrogen. Bone tankage, a by-product of the packing houses, contains $2\frac{1}{2}$ to 9 per cent of phosphorus. Unacidulated bone phosphate is not readily soluble in water and becomes available to crops slowly, so that rather larger

quantities of the element must be applied in this form than it is expected a single crop will remove. When 300 to 400 pounds of ground steamed bone meal are used per acre, it will supply sufficient phosphorus for from three to five crops, depending largely on kind and yield.

Natural phosphates.—The chief supply of phosphorus for soil improvement is from natural phosphate beds. These are widely distributed over the earth, the most important deposits being in the United States, Canada, France, Spain, Norway, and north Africa. More than half of the world's output of these phosphates is produced in the United States. The principal phosphate beds in this country which have been worked are in Florida, Tennessee, and South Carolina. Enormous deposits, however, have recently been discovered in adjacent parts of Utah, Idaho, and Montana. Natural phosphate deposits are prepared in two ways for application to the soil, (1) by grinding the material to an extremely fine condition which is known and sold as raw phosphates or floats; and (2) by treating the ground material with sulphuric acid so as to form acid phosphate or superphosphate.

Raw phosphate or floats.—Rock phosphate varies greatly in content of phosphorus, ranging from 9 to 18 per cent, though the usual limits are 11 to 15 per cent. Even when ground to extreme fineness this material is dissolved in the soil with very great difficulty and becomes available to crops slowly. Certain crops, however, have greater power to secure their phosphorus from this source than others. The chief process by which this material is made available is through the action of carbon dioxid set free by the decomposition of organic matter in the soil. It is very necessary, therefore, that this material be used only when it is intimately mixed with some form of actively decomposing vegetable matter. This occurs when it is thoroughly incorporated with barnyard manure or applied as a top-dressing on some green-manuring crop which is being plowed under, or is applied to a soil naturally containing large quantities of vegetable matter, such as peat or muck soils. When used under these conditions rock phosphate is often as profitable to crops having a long period of growth as either of the other forms mentioned. From 500 to 1,000 pounds per acre of finely ground phosphate is commonly applied once in three or four years.

Acid phosphate.—In order to make the phosphorus or rock phosphate more readily available than in its natural condition it is very generally treated with sulphuric acid. Crude sulphuric acid and raw rock phosphate are mixed in about equal proportions, so that the percentage of phosphorus in the mixture is about one-half that in the raw rock phosphate, though essentially all of it is made available to

crops. The reaction of the sulphuric acid with the calcium phosphate produces in addition to acid phosphate, calcium sulphate (gypsum), to which may be attributed some of the benefit secured by the use of the acid phosphate.

On account of its ready availability, acid phosphate may be used in moderate amounts so as to supply only the phosphorus needed by the crops of one or two years. Since it usually has 6 or 7 per cent of phosphorus, crops requiring from 12 to 14 pounds of that element would need 200 to 300 pounds of the acid phosphate to furnish sufficient phosphorus for a single year. Where the crops grown are such as require large supplies of this element, as in the case of clover, alfalfa, cabbage, turnips, and certain other crops, a larger application would be better.

Slag phosphate.—When pig iron from ores rich in phosphorus is converted into steel by the basic process in which an excess of lime is used, a by-product, or basic slag, results. When produced by proper methods, the basic slag contains about 8 per cent of phosphorus, together with a considerable quantity of lime, from which the slag may derive a part of its benefit to the soil. Slag phosphate is produced in large quantities in Europe, and to some extent in the United States.

Potassium in the soil (Ref. No. 4, pp. 214, 215).—Potassium exists in large quantities in most soils, having been left as a residue from the incomplete decomposition of minerals rich in that element such as feldspar and mica. The total amount in sand, silt, and clay soils varies from 0.5 to 2.5 per cent. A large part of this is still combined with silica in an extremely insoluble form, and it becomes available only through the further decomposition of these silicates. The availability of these great natural stores of this element depends largely upon the presence of an abundant supply of organic matter in the soil. Peat and muck soils, which have been chiefly formed from vegetation which has grown in water or in very wet marshes, have usually had a considerable portion of the potassium leached out after the death of the plants, so that the resulting peat or muck contains relatively small quantities of this element. The average content of potassium in muck and peat soils is only from one-twentieth to one-fiftieth of that contained in upland earthy soils. It is true that the rapid decomposition of the organic matter of such soils which takes place when they are drained and broken generally leads to a fair supply of this element for a few years, but in practically all cases heavy applications of potassium are required sooner or later, and of phosphorus also in most cases.

Potassium taken by crops (Ref. No. 4, p. 213).—Cereal crops require relatively small amounts of this element, ranging from 20 to 40 pounds per acre annually, of which from one-third to one-fifth only is con-

tained in the seed, the greater portion being left in the stalk or straw. Corn, potatoes, cabbage, and most truck crops require relatively large supplies, varying from 60 to 100 pounds per acre, depending on yield and somewhat on kind of plant. Tobacco, for instance, requires unusually large quantities of this element. The legumes, especially clover and alfalfa, which are used as hay, also contain large quantities, alfalfa frequently removing as high as 150 pounds of this element per acre in the 5 or 6 tons grown annually. Essentially all the potassium which truck crops and hay contain is removed from the farm when they are sold, while in the growing of cereals of which only the seed is usually sold, relatively small amounts of this element are lost from the farm.

Soils needing potassium (Ref. No. 1, p. 197).—From the foregoing it is evident that potassium-bearing materials are especially needed under the following conditions: (1) On muck and peat soils; (2) on upland soils low in potash and of coarse texture, such as sandy soils; and (3) in the growth of certain truck crops and of hay, which require unusually large quantities of this element.

Potassium-bearing materials (Ref. No. 7, pp. 278–287).—The most important sources of commercial potassium are the deposits of the Stassfurt region, in Germany. (Ref. Nos. 4, pp. 216–218; 5, pp. 529–531.) The potassium exists in various salts, so that the raw product as mined varies greatly in the amount of potassium contained. Some of these salts are used directly upon the soil where the distance of haul is not too great. Kainit, one of these salts containing from 9 to 10 per cent of potassium, is very largely used in Germany and is imported to some extent into this country. The salts of potassium used most as fertilizers in this country, both alone and in the manufacture of complete fertilizers, are potassium sulphate and potassium chlorid (muriate of potash). It has been generally held that the chlorin in the latter material is injurious to certain crops, especially to potatoes and tobacco, and for these crops the use of the sulphate is usually advised.

The use of potassium salts.—When potassium salts must be depended upon to supply all or essentially all the potassium, from 100 to 300 pounds of muriate of potash must be used annually. Such crops as potatoes, sugar beets, and cabbage require relatively larger supplies than grain. Larger quantities should be used on sandy, muck, or peat soils than on loam or clay-loam soils. The salts should be spread evenly and should be well worked into the soil. Where potatoes are to be grown the muriate should be applied the fall before or the sulphate of potash used in the spring. Heavy applications of muriate in the spring tend to roughen the skin of the potato. When a large part of the crops grown on the farm are fed

to stock and the manure returned to the soil, very little potassium need be purchased except on farms located on marsh soils.

EXERCISES, LESSON VII.

Materials required.—Sodium nitrate, muriate of potash, sulphate of potash, kainit, acid phosphate, rock phosphate, bone meal, and of as many other fertilizer salts as possible; four 3-gallon crocks; $\frac{1}{2}$ bushel of moist sand or loam; a handful of corn; a small teaspoon, a tablespoon; two or three cups.

Solubility of fertilizer materials (Ref. No. 4, p. 240).—Place a teaspoonful of sodium nitrate in a cup and fill the cup two-thirds full of water. Stir for a few minutes. What happens to the fertilizer? When is a fertilizer considered soluble? Try the same test on muriate of potash, sulphate of potash, kainit, acid phosphate, rock phosphate, and bone meal.

Fertilizer material in hill versus broadcast application.—Fill four 3-gallon crocks with moist clay or silt loam soil and treat as follows:

(a) In the center make a hole about 2 inches deep and place in it three kernels of corn. On top of the corn place a tablespoonful of muriate of potash or any one of the other potash fertilizers; cover and water when necessary.

(b) Repeat as in (a), but place the tablespoonful of the same kind of fertilizer 2 inches deep and 3 inches away from the corn kernels. Cover and water when necessary.

(c) Repeat as in (a), but use only a small teaspoonful of the same kind of fertilizer.

(d) Determine the area of soil surface in this crock and apply as much muriate of potash as is equivalent to a 400-pound application per acre. Mix the fertilizer thoroughly with the top 4 inches of soil and plant three kernels of corn 2 inches deep.

Give all the crocks the same care and note carefully the effect of the different treatments upon the growth of the corn.

(e) A small teaspoonful of potash fertilizer weighs one-fourth of an ounce. Calculate the amount of fertilizer required per acre if each hill were treated as in crocks (a) and (c), the corn being planted in hills $3\frac{1}{2}$ feet each way.

(f) Similar tests may be made, using phosphate materials or mixed materials. What conclusions may be drawn from the results of these tests?

PROBLEMS.

1. An acre of dry sand or sandy soil 8 inches deep weighs in round numbers 2,500,000 pounds; a clay or silt loam, 2,000,000 pounds; and a peat, 350,000 pounds. How many times heavier is sand than peat?

2. A productive silt loam analyzed 0.11 per cent phosphorus. How many pounds of this element are contained in an acre 8 inches deep?

3. A 75-bushel corn crop removes from an acre approximately 16 pounds of phosphorus. How many such crops of corn can be supplied by the total amount of phosphorus in an acre 8 inches of that fertile silt loam?

4. A certain clay loam contains 0.049 per cent phosphorus. How many more pounds of this element are contained in an acre 8 inches of the fertile silt loam than in this clay loam?

5. How many 75-bushel corn crops will the phosphorus in an acre 8 inches of the clay loam supply? Is any soil able to produce a 75-bushel corn crop every year until the soil supply of phosphorus is entirely exhausted? Explain. (Ref. No. 5, pp. 107, 108.)

6. A silt loam soil was cropped almost continuously for 63 years. It is now in a badly exhausted condition and analyzes only 0.04 per cent phosphorus. A sample of this same soil which was never cropped contained 0.074 per cent phosphorus.

Determine the apparent average annual loss of this element from the soil during those years.

7. One ton of clover hay contains approximately 5 pounds of phosphorus and timothy hay about $2\frac{1}{2}$ pounds per ton. How many pounds of phosphorus are sold from the farm when a farmer sells 30 acres of clover averaging $1\frac{1}{2}$ tons per acre and 25 acres of timothy averaging $1\frac{1}{2}$ tons of hay per acre? What is the value of this phosphorus at 10 cents per pound?

8. One ton of wheat bran contains about 25 pounds of phosphorus and cottonseed meal the same amount. How many pounds of phosphorus does a farmer bring to his farm when he buys 20 tons of bran, 8 tons of cottonseed meal, and 15 tons of clover hay? Is all of this phosphorus added to the soil?

(a) The loss of phosphorus in the feeding transaction may be considered 20 per cent, the manure being hauled directly to the field. How many pounds of phosphorus will this farmer add to his soil through the purchase of these feeds?

9. Twenty-five per cent phosphoric acid is equivalent to what per cent phosphorus (P)? Fifty pounds of the compound phosphoric acid (P_2O_5) is equivalent to how many pounds of the element phosphorus (P)?

10. One phosphorus fertilizer contains 14 per cent phosphorus, while another is marked to contain 30 per cent phosphoric acid. Which contains the more phosphorus, and how much more?

11. When rock phosphate containing 30 per cent phosphoric acid can be delivered for \$8 a ton, what is the cost of 1 pound of phosphorus?

12. When acid phosphate analyzing 16 per cent phosphoric acid can be had for \$16 a ton, how many pounds of phosphorus can be purchased for a dollar? Compare this with rock phosphate. Which of these two fertilizers is soluble?

13. The phosphorus contained in rock phosphate analyzing 13 per cent phosphorus and applied at the rate of 1,000 pounds per acre is sufficient to supply about how many 75-bushel corn crops?

14. How much basic slag analyzing 8 per cent phosphorus must be added per acre to return to the soil approximately the amount of phosphorus removed by three clover crops averaging 2 tons of hay per acre, two 75-bushel corn crops, and one crop of timothy hay averaging $1\frac{1}{2}$ tons per acre?

15. One thousand pounds of milk contains 0.8 of a pound of phosphorus. How much phosphorus is contained in the milk produced by one cow in a year if she averages 30 pounds of milk per day?

16. How many pounds of potassium are contained in a heavy clay loam analyzing 2.5 per cent potassium? In a peat containing 0.5 per cent potassium?

17. A poor, sandy soil analyzed 0.68 per cent potassium, while a peat analyzed 0.3 per cent of this element. In comparing the percentages, what per cent more of potassium does the sand contain than the peat?

18. In comparing the actual number of pounds in an acre 8 inches deep, what per cent more of potassium does the poor sand in problem 20 contain than the peat? Explain the different results obtained in these two problems.

19. A 1,600-pound tobacco crop removes from 1 acre about 75.5 pounds of potassium. How many such crops will the potassium supply that is contained in an acre 8 inches deep of a silt loam analyzing 2 per cent potassium?

20. A 4-ton alfalfa crop removes from 1 acre about 95.5 pounds of potassium. What is the value of the potassium contained in 40 tons of alfalfa hay when 1 pound of this element is worth 6 cents per pound?

21. Sixty-five pounds of potash (K_2O) is equivalent to how many pounds of potassium? Fifty per cent potash is equivalent to how many per cent potassium?

22. A man can buy muriate of potash analyzing 43 per cent potassium for \$45 per ton and kainit containing 12 per cent potassium for \$15 a ton. Both are soluble fertilizers. Which will give him the more potassium for his money?

REVIEW QUESTIONS, LESSON VII.

1. How many pounds of phosphorus are there in the surface 8 inches of a silt loam soil if the chemical analysis shows that it contains 0.07 per cent of this element?
2. State ways in which phosphorus may be lost from the soil.
3. How may these losses be replaced?
4. Why is dairy farming less liable to exhaust the phosphorus of the farm than grain raising?
5. Name the chief sources of phosphorus used for fertilizers.
6. Mention the principal kinds of phosphate fertilizers available for use in this country.
7. Which contains more phosphorus, rock phosphate or acid phosphate?
8. How should rock phosphate be used? How may acid phosphate be applied?
9. Do legumes such as alfalfa and clover remove phosphorus from the soil?
10. How is the phosphorus content of phosphate fertilizers commonly expressed?
11. In what part of the plant is most of the potassium left when the crop matures?
12. How does potassium differ in this respect from phosphorus?
13. How much potassium is usually removed from an acre by a crop of corn?
14. What plants draw most heavily on this element?
15. How does the amount of potassium compare with that of phosphorus in ordinary clay loam soil?
16. What kinds of soil are most lacking in potassium?
17. What is the chief source of potassium fertilizers, and what are the most important kinds?
18. About how much muriate of potash would you apply to muck soils on which you expected to grow a heavy crop of cabbage?
19. When should muriate of potash be applied to ground on which potatoes are to be planted?
20. Under what conditions is it unnecessary to use potassium fertilizers on heavy soils?

LESSON VIII. MANURES AND FERTILIZERS.

In the general use of the terms, manures are thought of as the waste materials from the care of live stock, while fertilizers include commercial materials of value to the soil because of their nitrogen, phosphorus, and potassium content. In this lesson we shall include as manures crops which are grown and returned to the soil, either indirectly through animal excrement and straw or other material used as bedding, or directly by returning the crop without harvesting solely for purposes of soil improvement. These subjects will be treated, respectively, under the headings of barnyard manure and green manures. The use of manures as soil builders has a distinctive advantage over commercial fertilizers because of the value which results from the decaying vegetable matter in addition to the nitrogen, phosphorus, and potassium which they furnish to the soil. Commercial fertilizers stimulate the growth of plants by supplying the three essential elements noted above in a concentrated and usually available form. The intelligent combined use of the two is best for both soil and crops.

BARNYARD MANURES.

(Ref. No. 1, pp. 113-121; or No. 7, pp. 316-347; or No. 9, pp. 229-236; or No. 6, pp. 131-148; No. 5, pp. 541-543; No. 4, pp. 158-160.)

Materials retained and voided by animals.—Much of the plant food removed from the soil by crops may be returned in the manure from animals to which the crops are fed. The actual amount of plant food so returned depends on the quantity absorbed by animals in their bones and flesh or converted into milk, and on the loss from the manure before it is returned to the soil. The more digestible the food and the younger the animal the larger is the portion retained in the form of bone and flesh. Hall, in England, found that when linseed cake was fed to fattening steers and milch cows, the distribution of the nitrogen, phosphorus, and potassium were as shown in Table III.

TABLE III.—*Distribution of nitrogen, phosphorus, and potassium contained in linseed cake when fed to fattening oxen and milch cows.*

	Nitrogen.	Phosphorus.	Potassium.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Content of 100 pounds of linseed cake.....	4.75	0.872	1.162
When fed to fattening oxen:			
Retained in meat.....	.21	.061	.017
Voided in urine.....	3.88	.039	.913
Voided in dung.....	.66	.772	.232
When fed to milch cows:			
Retained in milk.....	1.33	.218	.116
Voided in urine.....	2.75	.031	.872
Voided in dung.....	.67	.623	.174

This table is of special value in showing the comparative quantities of nitrogen, phosphorus, and potassium retained in meat and milk; also in the comparative quantities of these essential elements shown to be voided in liquid and solid excrement. It emphasizes the cost of producing milk from the fertility standpoint, and it clearly shows the importance of saving the liquid manure and returning it to the soil. Hopkins shows that as a general average for dairy farming, cattle feeding, and sheep feeding, practically one-third of the organic matter, three-fourths of the nitrogen, and three-fourths of the phosphorus contained in the feed and bedding are recovered in the total manures. Nearly all of the potassium may be recovered except that sold in milk.

Value of barnyard manure.—From a large number of chemical analyses it has been determined that the average sample of fresh manure, including bedding used in absorbing the urine, contains about 10 pounds of nitrogen, 2 pounds of phosphorus, and 8 pounds of potassium per ton of material, varying with the age of the animal and the feed. Estimated upon the fertility value of the three essential elements nitrogen, phosphorus, and potassium, fresh barnyard

manure is worth from \$2.50 to \$2.75 per ton. After being exposed in the open yard for a few months, 2 tons of fresh manure decomposes to about 1 ton, with an analysis showing 10 pounds of nitrogen, 3 pounds of phosphorus, and 8 pounds of potassium, having a fertilizer value of from \$2.60 to \$2.85 per ton. These estimates do not include the value to the soil of the organic matter furnished by manure. The comparative value of manures voided by different animals will be found in the references. It is highly important in farm practice to understand that the kind of feed given to farm animals has a very close relation to the value of the manure voided. The richer the feed in nitrogen content, the more valuable will be the excrement produced. Therefore, one who winters live stock largely on corn fodder and straw will have much less valuable manure to return to the soil than one who adds clover hay, alfalfa, or grain to the feeding ration.

Losses from barnyard manure.—The losses from manures on farms of the United States is hundreds of millions of dollars annually. This is poor economy, considering the needs of the farms from which this immense loss occurs and the fact that much of it could be avoided by good management. The losses occur largely in two ways: (1) From liquid manures not being saved, and (2) from storing and exposure.

Loss of liquid manure.—The collection and return to the soil of the liquid portion of the manure is evidently the most difficult problem. About one-half of the fertilizing value of barnyard manure is contained in the liquid portion. Storage in cisterns is only partially successful, especially in the Northern States, where the freezing of the liquid during the winter makes its distribution difficult or impossible. On the whole, the most satisfactory method for conserving liquid manure on the farm is to absorb it in the bedding. As much straw, cut or shredded cornstalks, or other refuse material should be used as may be necessary entirely to absorb the liquid. (Ref. No. 4, pp. 160, 161.) Peat or moss, when available, is a far more effective absorbent than straw. The dust from this material, however, makes it objectionable for bedding dairy cattle. Finely ground phosphate rock is often used upon the floors as an absorbent after cleaning the stables. Such use also helps the phosphorus of this material to become available to plants after the manure is applied to the soil and decomposition begins.

Losses from storing manures (Ref. No. 3, pp. 598–602; or No. 4, pp. 175–181).—There are two ways in which fertility is lost from the manure pile while stored. First, by leaching out of much of the soluble and most valuable part, and second, by fermentation and heating, which causes loss of nitrogen in the gaseous form. Leaching should be prevented by having the manure pile either covered or so completely built that no more water is absorbed by the manure than is necessary to keep it in a moist condition. In the South and

other regions of considerable winter rainfall some form of manure shed should be provided. In some localities of the North the winter rainfall may be not more than sufficient to keep the manure properly moist. However, alternate wetting and drying is especially objectionable on account of the large loss of nitrogen it causes. Overheating from fermentation is most likely to occur in horse manure. (Ref. Nos. 1, p. 149; 7, p. 312.) This should if possible be mixed with cow manure, and if not, it should be kept sufficiently moist and compact to prevent overheating, or firefanging. Under the very best care it is practicable to collect and return to the soil about 85 per cent of the plant-food elements contained in the fresh manure. If three-fourths of the food elements taken from the soil by the crops which are fed to animals is voided in the manure, and 85 per cent of this can be returned to the soil, about two-thirds of the fertility contained in crops removed from the land and fed to animals can be returned to the soil in manure. Every effort should be made to make the fraction actually returned as large as possible.

Application of manure to the land (Ref. Nos. 1, pp. 165-172; or 3, pp. 602-609; or 4, pp. 181-186).—On account of the danger of loss of plant-food material from manure undergoing decomposition, it is best to apply it directly to the land as produced. This can usually be done in general farming. Coarse and fresh manure can be used on rank-growing crops such as corn, cabbage, sugar beets, etc., by applying it during the winter as produced to land to be planted to these crops. These crops can then be followed by those to which it is not well to apply manure directly, such as potatoes and other crops affected by fungus diseases which are encouraged by the raw manure. When it is to be applied to sandy soils, however, the manure should be composted, as otherwise the decomposition in the soil of the bedding will dry out the soil too much. Fine or well-rotted manure can also be used to great advantage as a top-dressing on meadow land or on pasture.

It is often thought that pastures do not need fertilization, but this is a great mistake, for since the animals are in the yards or stables part of the time and are storing up the elements of plant food in their bodies, they cause a constant drain on the soil of the pasture which is not made good by the manure dropped in the pasture. This loss must be met by additions either of manure from the stable or of commercial fertilizers.

Few crops will give better returns for manure applied than hay, especially timothy and other true grasses. Clover, alfalfa, and other legumes will respond wonderfully to manure; but since these plants can secure most of their nitrogen from the air, if necessary, they should be made to do so by supplying them with fertilizers containing the other elements only. This will permit the use of all of the manure

of the farm on crops which require the nitrogen as well as the other elements, and so increase the fertility of the whole farm. Manure applied to meadow land should be well composted, so that its fertilizing constituents are largely soluble and will be leached down into the soil at once, and the straw used as bedding will be rotted and will not be raked up with the hay.

As a rule it is better to plow manure under when applied on such crops as corn, cabbage, sugar beets, etc., because then it causes no difficulty in cultivating these crops, as it often does when applied as a top-dressing after the land is plowed. But on heavy clay soils the manure is more effective when applied as a top-dressing and cultivated into the soil, because then it is more readily oxidized than when plowed under. It can be used as a top-dressing in this way if well rotted.

The rate at which the manure should be applied will, of course, be determined in part by the supply produced on the farm. But it is much better to use small quantities frequently than large quantities seldom. Four or five tons to the acre every three years is better than 12 or 15 tons every nine years. The even distribution of manure, such as can be accomplished with the manure spreader, is also a matter of great importance.

GREEN MANURES.

(Ref. No. 7, pp. 348-362; or No. 6, pp. 342-348.)

Decaying vegetable matter in some form is indispensable for keeping a soil in the best physical condition and in the highest state of fertility. If the system of farming is such that not much live stock is fed upon the farm, the manure will not be sufficient to supply the needed amount of vegetable matter to the soil, and some other means should be adopted as a substitute. In such a case, the most practical method is to grow crops to turn back to the soil. Such crops are called green manures.

There are two ways of furnishing green manures: (1) A crop is produced during the regular growing season, but instead of being harvested, it is returned to the soil. This method may be necessary in the North where the growing seasons are short; (2) a crop to return to the soil is grown with the regular harvested crop and left on the ground from the harvest; or a crop is sown after the regular crop is removed and gets its growth during the fall and winter months, in which case it is called a cover crop. This method of green manuring is now much used in the Southern States.

In addition to the value to the soil of vegetable matter supplied, the following benefits come from the green-manure crops: (1) Where a cultivated crop has been grown and harvested, considerable available plant food is left in the soil which may be taken up in the growth

of the cover crop to be given up again from decay in the soil to the succeeding regular crops. Where no cover crop is used, there may be considerable leaching during the fall and winter, especially of the nitrogen compounds. (2) When a cover crop is on land during the heavy rains of fall and winter, the covering and the roots in the soil are very effective in preventing erosion. This is especially true in the case of clay soils. (3) When legumes are grown for green manures, the nitrogen content of the soil is much increased. This important fact should not be overlooked.

The crops most commonly grown for green manuring are: Non-leguminous—rye, wheat, oats, and barley; leguminous—cowpeas, soy beans, crimson clover, red clover, sweet clover, bur clover, Japanese clover, and vetch.

COMMERCIAL FERTILIZERS.

(Ref. No. 7, pp. 449-475.)

Since the time when it became generally accepted that one or more of three essential elements of plant growth, viz, nitrogen, phosphorus, and potassium, are most apt to be found in soils in such small quantities as to limit crop production, there have gradually sprung up commercial enterprises organized for the purpose of manufacturing and distributing materials containing one or more of these so-called essential elements. Usually substances containing two or three of these elements are mixed in different proportions and put upon the market under different names, such as corn grower, cotton grower, potato grower, etc. When materials thus manufactured and sold contain the three essential elements, they are called complete commercial fertilizers. There are hundreds of brands of complete fertilizers upon the market, and the number is fast increasing. Materials commonly used for complete fertilizers are sodium nitrate for nitrogen, acid phosphate for phosphorus, and potassium chlorid (muriate) or potassium sulphate for potassium. In the higher grade, and consequently higher priced, complete fertilizers the materials used are comparatively pure; in the lower and cheaper grade some material called a filler is often used in the mixture. At the present time ground limestone and peat are used to some extent as fillers.

Use of fertilizers in the United States.—The largest part of the fertilizers used is applied to those soils which have been longest under cultivation. This statement is particularly applicable to the Southern States where the sandy soils, the long hot seasons, and especially the single-crop system (culture of cotton, a nonleguminous crop) have very much depleted the humus content and general fertility of the soils. Quoting from the United States Census Report:

In 1909 the farmers of the United States reported the expenditure of \$114,882,541 for fertilizers, of which \$75,752,296, or 65.9 per cent, was spent by the farmers of the

South. The farmers of the Atlantic division alone spent \$59,625,130, or more than half of the total. Most of the expenditure for fertilizers outside of the South was reported from the three northeastern divisions of the country, the New England, Middle Atlantic, and East North Atlantic.

Fertilizer control.—Most of the States have enacted laws to govern the sale of fertilizers. The laws generally require that the containing packages shall show the guaranteed analysis of the materials. The analyses are commonly reported in terms of nitrogen or of ammonia, total and available phosphoric acid, and potash.

Fertilizers containing about 2 per cent ammonia, 8 per cent phosphoric acid, and 2 per cent potash are very commonly found in the market and are often known as 2:8:2 goods. Such fertilizers are considered low grade.

As stated before, nitrogen may be calculated from ammonia by multiplying by 0.82, phosphorus from phosphoric acid by multiplying by 0.4366, and potassium from potash by multiplying by 0.83. Thus 2 per cent of ammonia $\times 0.82 = 1.64$ per cent of nitrogen.

The use of mixed fertilizers.—There are so many different kinds of soils in the United States, so many different crops grown, and so many different conditions to meet, that it is wholly impracticable in this treatise to attempt to give directions with regard to proportion and quantity in the use of mixed fertilizers. The agricultural experiment stations of the different States have conducted soil surveys, soil analyses, and soil-fertility experiments until there is now a considerable fund of information with regard to the best use of fertilizing materials for the types of soil and crops grown in each State, and it is best to apply to one's own experiment station for this information. In general, it is well to decide first how much nitrogen, phosphorus, and potassium should be added to the soil for the crop to be grown; then to compute the quantity of the different compounds of these elements necessary to furnish what is desired; and, finally, to use the materials which will furnish the elements needed in available form at the least cost.

Home mixing of fertilizers.—Of late years farmers are beginning to buy separately the fertilizer materials and to mix these materials themselves as desired. Some of the advantages of this practice are: (1) One can add to the soil at any time any one of the fertilizing elements alone, or any combination of the elements, in the proportions desired. (2) Many grades of complete fertilizers can be made, as needed for different crops and soils, from only three materials. (3) The buying and application of the fertilizers can be done more intelligently, and often more cheaply. (Read pp. 476-490, Ref. No. 7.)

EXERCISES, LESSON VIII.

Materials required.—A pint of muck or peat; two wide-mouthed pickle bottles; three or four ounces of ammonium carbonate; two pieces of woolen cloth for strainers; two glass tumblers.

1. *Why barnyard water is colored.*—Every farmer and farm boy has observed the peculiar color of barnyard water and has detected strong ammonia odors in the horse stable. The one condition is closely related to the other in this way: The nitrogen of an animal body is excreted through the urine. The principal nitrogenous substance in urine is urea. Urea is acted upon by fermenting organisms producing the compound ammonium carbonate which, with moisture, has the ability to dissolve organic matter. This accounts in a large degree for the brownish color of barnyard water. This solvent action may be observed as follows:

Place a handful of peat or muck in each of two wide-mouthed pickle bottles. Add about half a cup of ammonium-carbonate solution to one, and a like amount of water to the other. Shake each for a few minutes, let stand about 20 minutes, then shake again for a few seconds. Run the liquid contents of each bottle through woolen cloth into glass tumblers and note color of liquids. Explain results.

PROBLEMS.

1. A ton of good average barnyard manure contains about 0.5 per cent nitrogen, 0.1 per cent phosphorus, and 0.4 per cent potassium. How many pounds of each of the elements are contained in 1 ton?

2. When nitrogen is worth $18\frac{1}{2}$ cents per pound, phosphorus 10 cents, and potassium 6 cents per pound, what is the value of the plant food contained in 1 ton of good manure?

3. A farmer applied 30 tons of good manure per acre to his tobacco land. About how many pounds of each of the fertilizing elements did he apply per acre in the manure? What may be considered the total value of the plant food applied?

4. How many pounds of each of the three fertilizing elements are applied when 8 tons of manure are applied per acre? What is the value of these fertilizing elements?

Under average good conditions about 40 per cent of the nitrogen is lost in the feeding transaction and production and handling of manure, about 20 per cent of the phosphorus, and about 5 per cent of the potassium (straw for bedding).

5. A 40-bushel barley crop removes from the soil about 48 pounds of nitrogen, 9 pounds of phosphorus, and 30 pounds of potassium. If 10 acres of such barley were fed and all the manure produced from this crop were returned to the same field, would there be a loss or gain, and how much of nitrogen, phosphorus, and potassium as compared with that contained in the soil before the crop was planted?

6. The amount of plant food removed per acre by corn, oats, and alfalfa is as follows:

Amount of plant food removed from the soil by different crops.

Crop.	Yield per acre.	Pounds per acre removed from soil.		
		Nitrogen.	Phosphorus.	Potassium.
Corn, bushels.	65	85	14	79
Oats, bushels.	50	50	8	37.5
Alfalfa, tons.	4	200	18	95.5

How much plant food would be lost in feeding 7 acres of corn averaging 65 bushels of shelled corn per acre, and 10 acres of oats, averaging 50 bushels per acre? (All straw used for bedding.)

(a) The nitrogen contained in the alfalfa crop may be considered the amount fixed from the air by that crop. How much nitrogen would be added to the soil if the manure produced from feeding 2 acres of alfalfa hay averaging 6 tons per acre were returned to the same field? Would there be a loss or gain of phosphorus, and how much?

(b) A man fed 20 acres of corn yielding 65 bushels of shelled corn per acre, 10 acres of oats yielding 50 bushels, and 5 acres of alfalfa hay yielding 5 tons per acre. All manure produced was used on the farm. What was the loss or gain of nitrogen in the feeding transaction?

(c) If 5 tons of cottonseed meal were fed during the time required to feed the crops in the preceding problem, what would be the loss or gain of nitrogen and phosphorus to the soil? One ton of cottonseed meal contains about 135 pounds of nitrogen and 25 pounds of phosphorus.

7. At the Hatch experiment station, Massachusetts, it was found that the drainage from the gutter behind milch cows contained 0.98 per cent nitrogen, 0.1 per cent phosphorus, and 0.73 per cent potassium. How many pounds of each of these elements were contained in a ton of this liquid?

(a) At the same station it was found that the liquid drained from a manure heap contained 1.5 per cent nitrogen, 0.043 per cent phosphorus, and 4.06 per cent potassium. Compare the fertility contained in 1 ton of this liquid with that in problem 7. What conclusions are to be drawn from these figures?

REVIEW QUESTIONS, LESSON X.

1. Name some of the factors which influence the amount of plant-food material that may be recovered in the manure produced from feeding.

2. In what form is most of the nitrogen voided from the animal body?

3. Compare the amount of phosphorus retained in milk with that retained in meat.

4. About what part of the nitrogen and phosphorus in feeds fed is recovered in the manure?

5. About what part of the plant food contained in feeds is returned to the soil?

6. How may the loss of the liquid manure be reduced to a minimum?

7. Explain how losses of plant food from manure occur.

8. Discuss the time and method of applying manure.

9. Discuss the condition manure should be in when applied to certain crops and soils.

10. How much plant food is contained in 1 ton of average manure, and what is its value?

11. What is a green manure? Under what conditions is it necessary to use green manures to retain or to increase the fertility of a soil?

12. What crops are best to use for green manuring?

13. What is a cover crop? Of what value are cover crops to the soil besides their manurial value?

14. What is a complete commercial fertilizer?

15. Is it better to use fertilizers of high or low grade? Why?

16. Discuss home mixing of fertilizers.

LESSON IX. SOIL ACIDITY AND LIMING.

(Ref. No. 1, pp. 242-248; or No. 5, pp. 160-164; or No. 6, pp. 313-319.)

A condition of the soil which effects important changes, including nitrification and nitrogen fixation, is that of acidity. Practically all soils formed in regions of moderately heavy rainfall and not

derived by glaciation from limestone rocks are found to be more or less acid. Liming is the only practical way for correcting acidity. It is also beneficial to the soil in several other ways. Nearly all of the vast area of sandy lands of the South, and much land of the North and Northeast, as well, need liming. Besides other related topics, there will be taken up in this lesson the means for detecting soil acidity, together with the different kinds of lime, the quantity of each to be used on the soil, and the methods of application.

Lime is not generally considered as a fertilizer, although calcium, the mineral element of lime, is present in certain soils to such a limited extent that some substance containing this element needs to be added as a plant food.

Reasons for soil acidity.—While the question of acidity is still under investigation, the following reasons for this condition in soils seem to be fairly well established: (1) The abnormal breaking down of large quantities of vegetable matter in lowlands poorly drained causes acidity. (2) Because of the greater water solubility of the basic compounds of the soil than of the acid silicates, the bases are removed more rapidly from leaching than are the acid compounds. Since cultivated areas leach more readily than wooded and pasture lands, they thus develop acidity more rapidly. (3) In cropping, the basic elements of plant food are taken more rapidly from the soil than are the acid elements. When crops are removed from the land, therefore, instead of being fed and the manures returned, an acid condition eventually results from this cause. Moreover, the basic elements are carried from the subsoil to the surface to some extent by the roots of plants, and it is a common experience to find the subsoil acid when the surface is still neutral or alkaline. (4) An acid residue is left in the soil from some fertilizers. Ammonium sulphate, for example, when applied to the soil gives up ammonia as a plant food and leaves sulphuric acid as a residue. It is thought, likewise, that when potassium sulphate is used in fertilizers, a part of the potassium becomes liberated, leaving an acid salt of potassium in the soil.

Objections to acidity (Ref. No. 7, p. 141).—Nitrification of organic matter does not take place readily in acid soils, although in the case of acid marsh soils which are well drained, the nitrification may be sufficient to supply nitrates for the rapid growth of most crops. Acidity in the soil, moreover, has much more detrimental effects in its influence on nitrogen fixation by certain tubercle-forming organisms than on the process of nitrification. The bacteria which form tubercles on medium red clover, alfalfa, sweet clover, soy beans, and some other legumes do not develop at all rapidly in acid soils, and when the soils are quite acid it is necessary to use lime to correct

the acidity in order to secure a good growth of these plants. Some other legumes, such as yellow lupine, serradella, and cowpeas are usually able to grow well on distinctly acid soils, though in some cases even these plants seem to be benefited by lime. The beneficial effect of lime on alfalfa and the other first-mentioned crops is in changing the reaction of the soil from acid to neutral or alkaline, while the benefit occasionally reported in the case of serradella and lupine is possibly due to the fact that on certain soils these plants do not find sufficient calcium for their growth, and the lime supplies this element.

Detection of acidity (Ref. No. 1, p. 247).—The presence of acidity may be detected in various ways. Perhaps the simplest method is by the use of litmus paper. This is cheap and can be purchased at any drug store. A strip of blue litmus paper is placed in the bottom of a drinking glass and covered with white blotting paper or filter paper on which the soil to be tested is placed. Clean rain water is added slowly until the soil and the litmus paper become damp. If the paper turns distinctly pink it shows that the soil is acid. It may be well to wait for ten minutes or more before coming to a final decision. The degree of acidity is roughly indicated by the rate at which the change in color takes place and its final intensity. Red litmus paper turns blue in the presence of alkalinity. It will often add to the interest and value of the test if strips of both red and blue litmus paper are placed in the bottom of the glass.

A method of determining the presence of limestone and the consequent absence of acidity is to drop dilute muriatic acid upon moist soil. Any perceptible bubbling, or effervescence, indicates the presence of lime. The character of this effervescence may easily be learned by dropping some of the acid upon a piece of limestone or marble, or into a little baking soda dissolved in water. The presence of lime in the subsoil may sometimes be shown by this test when the surface gives no positive test. A failure to detect the presence of limestone by this test should not be interpreted as proof of acidity in the soil.

The best indication of the need for lime is the type of plant growth that the soil bears. Where alfalfa, red clover, and sweet clover grow vigorously no lime is needed. The predominance of sorrel, broom sedge, white daisy, or redtop indicates a need for lime.

Correction of acidity (Ref. No. 7, pp. 382–390; or No. 6, pp. 303–313).—The practical means for correcting the acidity of soils are (1) drainage, where needed, and (2) the application of lime in some form. Lime suitable for use in correcting soil acidity may be in any one of three forms. The first is the carbonate; second, burned or quicklime; and third, water-slaked or hydrated lime. These forms

of lime are different compounds of the element calcium, and any one of them will neutralize the acidity of soils. The carbonate occurs in different forms, among which are limestones, marl, chalk, shells of mussels, and refuse lime from sugar-beet factories. (Ref. No. 5, pp. 160-182.) Any of these forms of calcium carbonate when ground sufficiently fine are well adapted for use in correcting soil acidity. Not only does this form of lime have a good effect upon the soil, but it is relatively convenient to handle. Whenever it can be applied at a reasonable price as compared with other forms of lime it should generally be used.

Quicklime, sometimes called lump lime, results from the burning of limestone. In the process of burning carbon dioxid is driven from the limestone as a gas, leaving the quicklime, chemically, calcium oxid, in lump form. Quicklime, like the forms of calcium carbonate, should be finely divided before it is mixed into the soil. This form of lime is caustic and disagreeable to handle.

Water-slaked or hydrated lime results from adding water to quicklime. This process produces a great deal of heat and causes a chemical reaction which results in the formation of calcium hydroxid. Hydrated lime is finely pulverized and, from this standpoint, is in good condition to apply to the soil. Quicklime is sometimes spread without grinding or slaking, and, if done during a rainy season, will soon become slaked by the water which falls upon it. In this case it is advisable to spread it more thoroughly by harrowing before working it into the soil.

Slaked lime, like quicklime, is caustic. It is not advisable to use these forms in excessive quantities, particularly on light soils deficient in organic matter, since they unduly hasten the breaking down of the vegetable matter of the soil. This process is accompanied by an increased formation of nitrates, which may be obvious in growing plants, but with a corresponding depletion of the soil, especially if the growing crop is nonleguminous. Caustic lime gradually unites with carbon dioxid and is thus converted into the carbonate. When heavy applications of caustic lime are mixed with sandy soils, a cementing of the sand grains sometimes takes place, causing a detrimental clodding condition. On the other hand, liberal applications of caustic lime produce a flocculating effect upon clay soils, which reduces clods and improves soils physically.

No harm can come to the soil from the use of any form of calcium carbonate, even in large applications, but it should be noted that large quantities of lime in any form are favorable to the scab of potatoes. The form and quantity of lime to use is a practical question depending primarily on the degree of acidity of the soil and the relative cost of available materials. The cost depends on grade of

material, original cost, fineness, freight, distance to haul, condition of roads, and handling.

When 100 pounds of pure limestone is burned it gives 56 pounds of quicklime, which, when slaked with water, will give 74 pounds of hydrated lime. Hence, for neutralizing acidity, 56 pounds of burned lime is equal to 100 pounds of limestone or 74 pounds of slaked lime. Relatively speaking, the application of 1 ton per acre of burned lime would be equivalent to the use of $1\frac{1}{2}$ tons per acre of slaked lime, or 2 tons per acre of finely ground limestone. On average acid soils such an application is ample for from three to five years, at the end of which time it might be advisable to use one-half the amount of the previous application. When limestone is used it should be comparatively fine, and it might prove in many cases more practical, and eventually more economical, to apply a larger quantity per acre than above noted at correspondingly longer periods of time. Where lime in any form is used for alfalfa, which commonly occupies the land from six to eight years, liberal applications are necessary. In a short rotation, where potatoes is one of the crops, it is advisable to make light applications of lime and to add the material during each cycle of the rotation following the harvest of the potato crop.

Lime may be applied at any season of the year when its use is convenient. It should be mixed with the soil as thoroughly as possible. For this reason it is better not to plow the lime under, but to apply it after plowing, following with the disk or other harrow. If applied just ahead of a tilled crop, such as corn, the cultivation of the crop will aid in mixing the lime into the soil. In a distinctly acid soil, where red clover is one crop of the rotation, it is well to apply the lime in preparing for the crop preceding the red clover. Surface application on grass land will give some benefit, but not so much as where the lime can be more thoroughly incorporated with the soil.

The application of lime by hand with a shovel is tedious, and it can not be spread very evenly in this manner. The fertilizer attachment of a grain drill will sow lime when it is granular and not damp, but will spread not more than one-half ton to the acre. It is a common practice to use a manure spreader for this purpose, placing a layer of litter upon the table before loading the lime. Moreover, where the use of some form of lime is an established practice on the farm, a lime distributor will prove a good investment. There are several kinds of these on the market. Satisfactory homemade distributors have been built by using the wheels from a laid-by mowing machine and constructing a box and the feeding apparatus.

Other benefits from the use of lime.—Besides correcting acidity, lime causes other benefits in the soil, the principal of which are (1) the improvement of the physical condition, especially of clays; (2) the im-

provement of the soil for the work of nitrifying bacteria; and (3) an increase in the beneficial results from potassium salts and phosphates. While there may still be some question as to the exact chemical changes in the soil from the use of lime, experimental work at different stations has now quite clearly proved beneficial results to the extent of profit from the use of lime with potassium salts, phosphates, or manures over the use of any of these alone. The extent of these benefits, of course, varies with the type of soil.

EXERCISES, LESSON IX.

SOIL ACIDITY AND LIMING.

Materials required.—Two long pickle bottles; a small quantity of clay soil; soft water; limewater; a bottle of dilute muriatic acid; some powdered limestone, marble dust, old wood ashes, coal ashes, air-slaked lime, baking soda, and quicklime; blue and red litmus paper; some common salt; a few sweet apples; a bar of soap; vinegar and sugar; samples of soil from the community; a few old cups and saucers.

The flocculating effect of lime on heavy clay (Ref. Nos. 1, p. 243; 4, p. 228; 7, p. 379).—In each of two long, clean pickle bottles put a teaspoonful of fine clay soil. Fill both bottles within 2 inches of the top with soft water. Into one bottle pour about three tablespoonfuls of limewater. Shake both thoroughly for two or three minutes and note the formation of floccules in the bottle containing the limewater. Set the bottles aside and note the comparative rate of clearing by settling. What is meant by soil flocculation? How does limewater aid in clearing the turbid water?

Simple chemical test for carbonates.—Effervescence occurs when muriatic acid comes in contact with carbonates. This is a simple chemical test by which carbonates may be determined.

(a) Place a quarter of a teaspoonful of powdered limestone in an old cup or saucer, pour on about a tablespoonful of dilute muriatic acid, and note results. What causes the bubbling or effervescence?

Apply this test to the following substances: Marble dust, wood ashes (old), coal ashes, air-slaked lime, baking soda, and fresh quicklime. What kind of gas is chemically combined in all carbonates? How does this gas differ from that given off by our lungs? What kinds of carbonates do most limestones contain? Baking soda?

THE USE OF LITMUS PAPER.

(Ref. No. 9, pp. 41-57.)

Litmus paper may be used to determine the reaction of liquids.—(a) Dip a small piece of blue litmus paper into an acid solution. What happens? Try a piece of red litmus paper. Any reaction? Acid turns blue litmus paper red.

(b) Dip a piece of blue litmus paper into an alkaline solution. Any reaction? Test with a piece of red litmus paper. What change takes place?

An alkaline solution turns red litmus paper blue. An alkaline solution is the opposite in reaction to an acid solution.

(c) Determine the reaction that pure water has on blue and red litmus paper.

Water is a neutral liquid, neither acid nor alkaline.

(d) By the use of blue and red litmus paper determine the reaction of the following solutions: A common salt solution, sweet apple juice, soapy water, and vinegar solution sweetened with sugar.

Litmus-paper test for acid soils.—Since an acid solution will turn blue litmus paper red, we can tell by use of blue litmus paper whether or not a soil is quite acid.

(a) Place about three tablespoonfuls of soil in a clean dish and moisten to a thick mud with clean, soft water. With a clean stick separate the mud into two portions and lay on one portion a piece of blue litmus paper. Press the other portion of wet soil down on the litmus paper; leave for five minutes, then carefully remove the upper portion of the soil and examine the paper. If it has turned pink or pink spots appear upon it the soil is acid.

(b) Place one piece each of red and blue litmus paper in the bottom of a drinking glass. Over this place white blotting paper or filter paper, upon which put three or four tablespoonfuls of soil. Now add clean rainwater slowly until the paper becomes damp. After 10 or 15 minutes note whether a change has occurred in the color of the litmus paper. If the blue litmus paper has changed to a pink color, the soil is acid.

Compare this test with (a) to determine which method is preferable.

(c) Repeat test (a) or (b) on other soils. Save one of the acid soils for the next exercise.

Lime is used to correct acidity in soils (Ref. No. 1, p. 251).—Place about three tablespoonfuls of acid soil in a clean dish and thoroughly mix with it about a quarter of a teaspoonful of air-slaked lime. Moisten the mixture and test with blue litmus paper as before. What effect did the lime have on the acid soil?

REVIEW QUESTIONS, LESSON IX.

1. How can acidity in soils be detected?
2. What are the objections to soil acidity?
3. Name some legumes that can tolerate soil acidity.
4. Describe lime carbonate, quicklime, and water-slaked lime.
5. Explain how lime neutralizes acids in soils.
6. Why is it undesirable to use quicklime in excessive quantities on light, sandy soils?
7. Discuss the relation of the fineness of pulverized limestone to the rate of application.
8. Describe three ways in which the application of ground limestone to a very poor acid clay soil may be of benefit.
9. When a soil is neutral or alkaline in reaction, what may be implied?
10. What becomes of the lime supply of soils?

LESSON X. MANAGEMENT OF SPECIAL SOILS.

The successful management of any soil depends on an understanding of its special characteristics. Its weak points must be recognized and corrected if possible, and crops which are best adapted to the soil should generally be grown. Among the soils which require special management are the sands, the clays, and marsh lands.

SANDY SOILS.

Sandy soils are low in water-holding capacity, are subject to being blown by the wind, and are low in elements of plant food.

Moisture of sandy soils.—Low water-holding capacity of sandy soil has been explained in discussing the relation of texture to the amount of moisture soils can retain. Moreover, small differences in the texture of sandy soils or the influence of small quantities of organic matter considerably increase the total amount of water held

during a season. This is because the additional quantity of water which the soil having the finer texture or the larger proportion of organic matter may hold is repeated after each succeeding rain, so that if showers come eight or ten times during a season and are followed by dry periods, the total quantity of water available to crops under the first-named condition is considerably larger than under the second. The capillary rise of water is comparatively fast in sandy soil, but it can not be raised from any great depth. The moisture of sandy soils which is retained by capillarity is more effectively used by the growing crop, however, than in the case of soils of finer texture. (Ref. No. 2, p. 161.) Besides, the portion of the rain falling as light or moderate showers after dry periods is more largely available to crops growing on sandy than on heavy soils. A rainfall of one-quarter inch will penetrate the sandy soils several inches and so reach the roots of the growing crop, while this amount of rain falling on a soil of fine texture will be absorbed and held so near the surface that it does not affect the roots of the plants, and practically all of it evaporates from the surface soon after the rainfall. The control of soil moisture in sandy soils can be effected by the methods discussed under prevention of evaporation, page 28. Rolling these soils after seeds have been planted has the effect of increasing the movement of the water to the seed bed, but the field must be dragged after the rolling to prevent the evaporation of water from the surface. It is desirable to plant seed more deeply in sandy soils than in heavier or clay loam soil. Clover, or other small seed, should be sown an inch or an inch and one-half deep, so that it will have sufficient moisture for germination.

The topography, or "lay of the land," and the distance to the ground water of sandy soils is a matter of considerable importance. Owing to the freedom with which the water of the saturated portion of the subsoil can move in sandy soils, the ground water table is usually quite level and does not rise as rapidly under hills of sandy soils as it does in hills of heavier soils. For this reason the upper portions of hills of sandy soils are usually so far above the ground water table that practically no water is drawn from the subsoil. On the other hand, when sandy soils are level or have only a very small slope, and the ground water table is 6 or 8 feet below the surface, a considerable amount of moisture may be drawn up far enough to reach the roots of growing crops.

Wind blowing of sand.—In addition to danger from smothering by drifting soil, crops growing on sandy soils are often very seriously injured by the cutting action of sand blown against them. Not infrequently a single sand storm of a few hours' duration coming in spring or early summer will do as much damage as a severe frost.

These windstorms usually do not have much chance to develop during the summer when the ground is more fully covered by growing crops. To prevent this danger of wind-blown sand the ground should be kept covered with growing crops as much as possible. Land on which potatoes have been grown may be seeded to rye at once after the digging of the potatoes, and, if desired, clover may be sown on the rye early in the following spring. In this way the ground is never exposed for any length of time to the wind. Fields on sandy farms should also be laid out in long narrow strips, so that the ground on which the tilled crop, such as corn or potatoes, is planted will alternate with strips bearing grain or grass which protects the ground.

Fertility (Ref. No. 7, p. 415).—Sandy soils are low in the total amount of plant food they contain, and often what they do have is rather unavailable because of the coarseness of the grains of which it consists. It is particularly desirable that the organic matter of such soils be increased, partly because by so doing the nitrogen can be best increased, and partly because the organic matter acts on the mineral matter in the soil so as to make it available for growing crops. For adding organic matter legumes should be used as far as possible, since they have the power of gathering nitrogen from the air. In the growing of these legumes, such as clover, soy beans, etc., the use of a fertilizer containing potassium and phosphorus is important. Lime is also often needed to secure satisfactory crops of alfalfa or clover. These plants can secure much of their nitrogen from the atmosphere, but they require the mineral elements from the soil just as all plants do. However, it is important to notice that in the decomposition of organic matter produced by the growing and plowing under of legume crops the phosphorus and potassium which was used in their growth become available to succeeding crops, and this further increases the value of legumes as fertilizers.

Crops for sandy soils.—The readiness with which sandy soils may be worked, even immediately following rains, especially adapts such soils to the growth of crops requiring considerable manual labor, such as vegetables and small fruits. The advantage which sandy soils have in this respect is so great that it offsets their low fertility and makes it preferable to use them for such purposes, even though fertilizers must be purchased in larger quantities than would be necessary on heavier soils. The low water-holding power of such soil also permits it to become warm much more quickly in the spring than heavier soils which contain much water, the evaporation of which keeps them cold. This higher temperature of sandy soils adapts them to certain crops requiring a high temperature, such as melons, tomatoes, and potatoes. The fact that sandy soils are subject to drought during periods of small rainfall in the summer makes them poorly suited to grass crops, which should grow all the season, especially when used

for pasture. This seriously lessens their value for such crops as sugar beets, cotton, or corn, which grow through the whole summer. On the other hand, some small grains, which make their growth very early in the season, are better adapted to such land. Crop rotation for light soil should be short. Many of the best rotations are of but three years' duration.

Live-stock farming on sand.—The use of pasture is still, and probably will long remain, an important factor in most lines of live-stock farming. This is partly because in grazing, stock harvest their own feed, and in this way greatly lessen the expense for labor. Since sandy soils, as we have seen, are poorly adapted to pasture grasses, they are not as well suited to most lines of live-stock raising as are heavier soils. However, it is frequently the case that considerable quantities of produce, grown in connection with truck raising on sandy soils, are not marketable and should be fed to some form of live stock. A small number of live stock, therefore, should usually be kept, even on sandy farms, the principal business of which is the growing of truck or vegetable crops.

CLAY SOILS.

Formation and location.—Clay soils are commonly formed by the settling out of fine sediment in standing bodies of water into which streams carrying the sediment have run. Such areas of standing water occur as lagoons along main river valleys like those of the Mississippi, Ohio, Missouri, and other large rivers. They were also formed in extensions of the Great Lakes which existed toward the close of the glacial period. Broad belts of extremely heavy clay soils were formed in this way along the southern shore of Lake Superior, along Lake Michigan in Wisconsin, and on the southern borders of Lake Erie and Lake Ontario. Many shallow lakes existed for a comparatively short time at the close of the glacial period. In these great areas heavy clay soils were formed. Lake Agassiz in Minnesota, North Dakota, and Manitoba (long since dried up) is one of the best illustrations of the formation of heavy clay soils. The clay soil of the Champlain Valley in New York has its origin in the same way. Some areas of heavy clay soil have also been formed along the seashore as deltas and in bodies of salt water formed by shutting off the main portion of the ocean. As stated in Lesson I, a residual soil from limestone is also an extremely fine clay. This is because the soil is made up of the insoluble portions of the rock, the soluble portions having been dissolved and carried away by percolating water.

Characteristics of clay soils (Ref. No. 7, pp. 95-99).—Clay soils owe their special character largely to their very fine texture. Their large water-holding capacity and poor underdrainage is the immediate result of this texture. As a secondary result they often have poor tilth and are liable under certain conditions to be cold during the

spring. They usually have a high content of potassium, and the phosphorus content is sometimes large. Their treatment, therefore, must be such as to overcome their peculiar difficulties and take advantage of their particularly strong points.

Drainage.—Since large portions of these heavy clay soils were formed as deposits in standing bodies of water, they very commonly have comparatively level surfaces. They therefore frequently have poor surface drainage as well as poor underdrainage. For general farming everything possible must be done to secure good surface drainage when the expense of tile is unwarranted. Tile drainage, however, is often necessary in order to permit the use of such land for crops requiring considerable tillage. This form of drainage for such land is usually profitable, even for staple crops. The expense, of course, varies, depending on the distance to an outlet, the presence of stones in the subsoil, and other factors. Ordinarily the expense is between \$20 and \$30 per acre. Since a tile system once carefully installed in clay soil will last almost indefinitely, the expense to be charged to the land is simply that of the interest on the investment, or from \$1.50 to \$2 per year. Indeed, the entire expense is very commonly recovered by the increase of crops in from one to three years.

Tilth.—The most serious difficulty in the management of heavy clay soils results from their poor tilth. Such soils are apt to bake and form large clods, so that preparation of a good seed bed and the cultivation of the crop is difficult and involves much extra labor. This poor tilth is due to the fact that the films of water surrounding the fine grains draw the particles so closely together when they dry that they are held with considerable tenacity. This difficulty may be overcome to a limited extent by increasing the amount of organic matter. Humus and vegetable matter in such soils has the effect of lessening the tendency to form clods. Thus, after a heavy clay soil has grown a crop of clover, or has been in grass for some time, it is easier to retain a good tilth than if it is kept in tilled crops continually. As before shown, liming of clays, especially with quicklime, produces a flocculating effect upon the soil and so reduces the tendency to clodding and greatly improves its tilth. Another extremely important factor is the moisture condition when they are cultivated. As before stated, when such soils are plowed or otherwise worked in a wet condition, they have a marked tendency to puddle and run together in such a way that very hard and resistant clods are formed. It is extremely important to do all the work of tillage on such land when the soil is in just the right condition of moisture, so that the clods will break down in the soil. This condition must be determined for each individual field and with a little practice can readily be recognized. Plowing clay land in the fall and

leaving it in the rough plowed form gives frost and weather an opportunity to break down the clods, causing them to crumble. Care must be taken not to attempt to work the land in the spring until the surface is dried off enough to permit harrowing or disking without causing puddling.

Crops for clay soil.—On account of their fine texture and the difficulty with which roots penetrate clay soils they are not well adapted to such crops as have coarse roots, which can not readily enter the soil. On the other hand, extremely fine roots of grass are able to find their way into the most dense clays and can therefore take advantage of the large water-holding capacity such soils possess. Small grains, such as barley and wheat, do well on these soils for the same reason. Vegetable and truck crops are, as a rule, very poorly adapted to heavy soils, because their roots usually find difficulty in penetrating the soil, especially in a climate characterized by frequent summer rains. This soil is particularly objectionable for the growing of potatoes, since it is very difficult to prevent the soil from baking and cracking after cultivation has stopped, thus permitting the sun to strike the tubers and cause sun scald. When all of these factors are taken into consideration, it is evident that such lands are best adapted to the growing of cereals, corn, alfalfa, clover, and grass, and that stock raising in which the grass is used for pasture is especially adapted to them.

Fertilizers.—Clay soils vary a great deal in chemical composition. This applies to practically all elements of plant food. Since potassium is almost always present in relatively large amounts, it is often unnecessary to add potash fertilizers. The phosphorus content, on the other hand, is frequently found to be comparatively low, as in the case of the heavy clay soils occurring in the Lake Superior and Lake Michigan region. Besides such soils frequently contain considerable iron, which tends to reduce the availability of the phosphorus. For this reason, and because heavy clays warm up rather slowly and vegetation is apt to be slow and backward, particularly in the spring, a good supply of this element in available form is desirable in such soils. The element phosphorus has a very marked effect in hastening the maturity of practically all crops, so that it is often possible by the use of moderate applications of phosphate fertilizer on cold soils to cause crops to mature from one to two weeks earlier than they would otherwise do. The amount of nitrogen in such soils is extremely variable. In many cases a considerable supply of organic matter containing this element occurs in clay soils as a result of their more or less marshy condition before drainage. This condition permitted the growth of considerable native vegetation, but lessened its decomposition. Soils of this character are usually found well supplied with nitrogen after drainage and cultivation. It often happens, however,

that a considerable part of this black humus is of a very resistant character, and after the more decomposable portion has been used up by a few years' cropping, the nitrogen does not become available rapidly enough to supply the needs of growing crops. Under these conditions nitrogen must be supplied by the growing of legumes, the use of barnyard manure, or in some other way. The amount of lime occurring in these soils is also quite variable. As a rule, soils which were formed in standing bodies of water contain a fair amount of this material, secreted by shell animals and deposited as the clay formed, and also derived from streams running into such bodies of water, which very commonly carry more or less lime. Nevertheless, clay soils of this character are often found which are very low in lime carbonate, or are even acid, so that lime must be used.

Erosion (Ref. No. 2, pp. 50-54; 3, p. 14).—The erosion of soil is a cause of much loss of fertility, and on hillsides, especially of clay soils, it often nearly ruins the fields eroded. Sandy soils are not so readily eroded as clay, because the coarser texture permits the water, except in beating rains or on frozen ground, to pass down into the soil instead of running off the surface. The most practical means of lessening or preventing erosion are: (1) Keeping a high content of decaying vegetable matter in the soil, (2) the maintenance of a grass sod where practicable, (3) the use of channels having a slight grade, keeping grass growing in the bottom where possible, (4) subdrainage, and (5) terracing. A high content of decaying vegetable matter in clay soils causes a texture of increased water-holding capacity, and thus less water will have to run off the surface. Land which is so steep as to give trouble from erosion should be kept in grass as much as possible. It is often possible to grow one intertilled crop on hillsides without danger so as to permit of a rotation, though a second or third year in succession of tilled crops would be followed by serious difficulty. Hillsides should sometimes be laid out in narrow plow lands along the slope and carefully planned so that the dead furrows when cleaned out may be used as channels with very slight fall to conduct the water along the hillside to well-grassed or otherwise well-protected main ditches extending up and down the slope. Deep plowing, which will increase the amount of water a soil may hold from a heavy shower, will lessen the amount which must run off the surface and consequently lessen erosion. The same principle may be still further followed by placing tile for subsurface drainage on springy hillsides, the soil of which would otherwise be kept saturated so near the surface that the water from rain must run off the surface, thus causing erosion. The extreme method of preventing erosion is through the use of terraces, which are sometimes necessary on steep sidehills, especially in the South and other sections where the rainfall is very heavy.

MARSH SOILS.

(Ref. No. 2, pp. 64-68.)

Marsh soils are those which are naturally wet most of the year and contain moderate or large quantities of organic or vegetable matter. Such soils are formed in marshes occurring along the valleys of the larger rivers, along seashores where they are known as tidal marshes, and generally throughout the area which was covered by the last glacial ice sheets, where they were caused by the gradual drying up of hundreds of shallow lakes and ponds. (Ref. No. 3, pp. 41-43.)

Composition.—Marsh soils vary greatly in chemical composition, especially in the amount of organic matter they contain. (Ref. No. 7, pp. 123-125.) It is customary to speak of those which contain moderate quantities of vegetable matter together with considerable quantities of soil and earthy matter as mucks, while those which consist largely of organic matter are called peats. As a rule, soils which would be termed mucks contain from 15 to 50 per cent of vegetable matter, while those which would be called peats always contain over 50 per cent and usually from 70 to 75 per cent of vegetable matter.

Drainage.—It is self-evident that the first need in the improvement of marsh lands is drainage. This has been briefly discussed in the chapter on that subject. In many cases the construction of good open ditches and surface drains is all that is necessary to permit cultivation of marshlands, but these must be made of large size. They should also be given sufficient depth to produce as much under-drainage as possible. Ditches from 6 to 8 feet in depth will drain land for a considerable distance on either side as well as carry very large volumes of flood water. It is important that such a ditch be given the proper cross section; that is, it must not be so wide at the bottom that the small stream of the drier portion of the year will shift back and forth over it, causing it to fill up. A narrow bottom will confine the smaller stream and cause it to keep the ditch clean. The slopes of the sides of the ditch should not be so steep that it will tend to cave in, and they should be grassed as far as possible. However, tile drainage is frequently necessary to permit the maximum use of marshlands. When peaty soils are to be tile drained it is frequently best to put in ditches where the tile lines are to be laid and allow the soil to settle for two or three years before the tiles are placed. If the ditches are then thoroughly cleaned out and the bottom lined, the tile can be placed and covered. In this way a line of tile will be much less apt to be distorted by irregular settling.

Fertility.—Marsh soils have certain marked peculiarities in regard to fertility. Their high content of organic matter, of course, always

means the presence of a large supply of nitrogen. This is usually so great that practically no attention need be given to this element, but it occasionally happens that acid marsh soils are so cold on account of their wetness that nitrification takes place with extreme slowness and there is not a sufficient supply of this element made available. Under such conditions the use of some form of lime to correct the acidity and hasten nitrification is very beneficial. This is discussed on page 62. Manure is often beneficial to marsh soils and should be applied when practicable. (See Ref. 3, p. 613.)

The most marked weakness of marsh soils is with respect to the chemical elements, phosphorus and potassium. While, of course, all of the vegetation which causes the accumulation of organic matter in the marsh contained potassium when it was growing, this element is often leached out of such soils as they accumulate to such an extent that there is not left sufficient to supply the needs of growing crops. For this reason barnyard manure or some commercial fertilizer containing potassium must be used. It is frequently found that marshlands give fair yields for a few years after reclamation before this marked need of potassium develops. This is because some of the vegetable matter most recently formed still contains considerable potassium, and this becomes available through its active decomposition. As a rule, however, fertilizers containing this element must be used on such lands within a few years after their reclamation. The phosphorus needs of marsh soils are quite variable. Marshes which were formed in regions containing considerable limestone, and especially in regions of glacial soils formed from limestone, usually contain a considerable quantity of phosphorus which was deposited in them from surrounding highlands and which becomes available to growing crops. It is often found, therefore, that marshes of this character are not acid and do not show a marked need of phosphorus fertilizers for some years after their reclamation and cultivation. Practically all other marsh soils do require phosphate fertilizers just as much as potassium. The large amount of organic matter in marsh soils may make profitable the use of raw rock phosphate with ordinary field crops. This cheap form of phosphate fertilizer therefore is often preferable to more expensive forms for use on such land.

On account of the unbalanced fertility conditions of these soils, it is usually much more economical, when farms contain upland as well as marshland, to use the barnyard manure produced on the farm on the upland soil, which requires the nitrogen which it contains as well as the other elements, and to purchase commercial fertilizers containing potassium and phosphorus for the marsh soils.

Physical management.—Marsh soils are usually very loose and light in structure, so that growing crops do not find a good foothold

in them and do not come in contact with a sufficient amount of the soil to supply their needs. This is particularly true when fine-rooted crops are to be grown. The use of heavy rollers to firm such soil results in great improvement in this respect. Not only does the rolling and firming of the soil have the effect of bringing the roots in direct contact with a much larger area of soil surface, but it permits a more rapid conduction of the heat from the surface downward. In this way the lower layers of the soil are warmed, and this greatly increases the growth of the roots and promotes bacterial changes, such as nitrification, to which the fertility of the soil is in part due.

Crops for marsh soils.—A great variety of crops have been grown on marsh soils on account of their large supply of nitrogen. They are especially adapted to crops which produce rank growth and require large quantities of this element, such as corn, cabbage, rape, turnips, beets, and potatoes, though, of course, the quality of sugar beets and potatoes grown on such land may not be quite so good as when grown on upland soil. Since marsh soils as a whole are apt to be cold and affected by local frosts, care should be taken in the selection of crops, especially in northern climates. Here corn and potatoes, for example, might be out of the question. On the other hand, cabbage, rape, turnips, hay, of which a mixture of timothy and alsike clover is perhaps the best, and grain to a limited extent when proper care is taken may be grown to advantage.

EXERCISES, LESSON X.

PROBLEMS.

1. A man had 40 acres of marsh land which produced on an average 1 ton of wild grass per acre, valued at about \$3 per ton. He spent \$1,000 in draining it. Now those 40 acres raise corn averaging 15 tons of silage corn per acre, valued at at least \$3 per ton. Determine this man's interest on his investment.

2. Fifteen tons of manure per acre were applied on a drained peat soil. How many pounds of phosphorus and potassium were applied? How big a crop of corn will this amount of potassium supply?

3. Two hundred pounds per acre of muriate of potash were applied to a muck soil. What was the cost of this application at \$46 per ton, and how many pounds of potassium per acre were applied? (See table 24, p. 157, Ref. No. 5.)

4. Compare the value of the manure applied in problem 2 with the cost of the potash fertilizer in problem 3.

5. A portion of a peat marsh was treated with manure at the rate of 15 tons per acre; another portion was treated with an application of 400 pounds of muriate of potash per acre, costing \$47 per ton. The first year the manured portion produced 10.5 tons of silage (green) corn per acre, and the second year a yield of 6 tons was secured without any further treatment. On the potash portion the corn averaged 14 tons the first year and 14 tons the second year, without further treatment. Compare the results produced with the cost of manure and fertilizer in this case.

6. On another marsh (muck), an application of a mixture of muriate of potash at the rate of 200 pounds per acre and rock phosphate at the rate of 800 pounds per acre produced 12.5 tons of silage corn per acre. An application of 25 tons of manure on

another portion produced 15.8 tons per acre. The rock phosphate cost \$10 per ton and the potash fertilizer \$46. How many more dollars' worth of plant food in the manure did it require to produce the gain in yield for that year?

7. A mixture of acid phosphate and muriate of potash in the proportion of 100 pounds to 60 pounds, respectively, was applied to a field at the rate of 150 pounds per acre. The field produced 14.5 tons of silage corn per acre as compared with 3 tons where no treatment was made. The acid phosphate cost this farmer \$16 per ton, and the potash fertilizer \$45 per ton. What was the cost of this fertilizer treatment, and what may be considered the interest on the fertilizer investment for that year?

A farmer owns a clay farm of 160 acres. For regular cropping purposes he has six 20-acre fields. His crops are alfalfa, corn (two fields each year), oats, wheat, and red clover. The alfalfa occupies a field for five years, then is plowed for corn. The crops on the other fields are, in the order named, corn, oats, wheat, red clover. Rye, or rye and vetch, are used as a cover crop following the crops of corn. The crops are so planned in the five fields not growing alfalfa that each year the farmer has two fields of corn and one field each of oats, wheat, and clover. The analysis of the soil on this farm is fairly uniform and shows per acre in the total 8 inches of surface 4,000 pounds of nitrogen, 2,000 pounds of phosphorus, and 24,000 pounds of total potassium.

8. If C stand for corn, O for oats, W for wheat, and CL for red clover, and A for alfalfa, fill in the blank below so that the order of cropping in each field will be as given above, and so that there will be for harvest each year one field of alfalfa, two of corn, and one each of oats, wheat, and clover.

Field.						
Year.	1	2	3	4	5	6
1	A					
2	A					
3	A					
4	A					
5	A					

9. Assuming that the plant food liberated from this soil during the average season is equivalent to 2 per cent of the total nitrogen, 1 per cent of the phosphorus and $\frac{1}{4}$ of 1 per cent of the potassium:

(a) From table 23, reference No. 5, page 154, determine whether sufficient of the plant-food elements, nitrogen, phosphorus, and potassium, would be liberated during a growing season on this farm to produce a 100-bushel crop of corn.

(b) Compute whether any of these plant-food elements is present in this soil in sufficient quantity to produce the maximum of any crop noted in table 23.

10. The yields of crops on the farm averages 4 tons of alfalfa hay per acre, 50 bushels of corn per acre with 2 tons of stover, 50 bushels of oats with $1\frac{1}{2}$ tons of straw, 25 bushels of wheat with $1\frac{1}{2}$ tons of straw, and 3 bushels of clover seed per acre with $1\frac{1}{4}$ tons of clover hay the first cutting, three-fourths tons clover straw from hulling, and one-half ton growth of clover to turn under for corn.

(a) If the farmer sells his alfalfa, the grain including the corn, and the clover seed, but returns to the soil all corn stover, straw, and clover; and if each ton of clover fixes in its growth 40 pounds of nitrogen, and each clover crop fixes 12 pounds of

nitrogen per acre from the growth of vetch: Determine the nitrogen balance to the soil of a field resulting from one period of the cropping system, not including alfalfa. (See table 23, Ref. 5, p. 154). What would be the result if cowpeas were grown in the corn and added 30 pounds of nitrogen to the soil each year?

(b) If the farmer feeds to live stock three-fourths of all produce grown, including alfalfa, and uses one-fourth for bedding; and if one-third of the organic matter fed is recovered in the manure, and if three-fourths of the nitrogen and three-fourths of the phosphorus likewise are retained from the feed and bedding; determine the balance of humus and nitrogen to the farm in any period of five years, resulting from this system. (Each ton of alfalfa grown may be considered as fixing 40 pounds of nitrogen from the air.) Compare this balance with the one obtained in (a).

(c) Figure how much phosphorus would be removed from the farm during each 5-year period from both the grain farming and the live-stock farming. How much 6 per cent acid phosphate would have to be added every five years to balance the amount of phosphorus removed?

11. Consider your own system of farming and figure a balance from the standpoints of humus, and the plant-food elements, nitrogen, phosphorus, and potassium.

REVIEW QUESTIONS, LESSON XI.

1. Why has sandy soil little ability to conduct water upward from lower layers?
2. Why is it true that sandy soils may use the water of a light rainfall more efficiently than heavy soils?
3. Explain why topography must be considered more carefully in the case of sandy soils than in the case of clay soils, especially in climates of moderate rainfall.
4. Explain why rolling a sandy soil aids in the germination of fine seeds.
5. In what ways may the injury due to blowing of sand be lessened or prevented?
6. What are the two chief causes of low fertility in sandy soils?
7. How can the nitrogen supply of a sandy soil be best increased and maintained?
8. What advantages has a sandy soil over a heavy soil?
9. What small grains are especially well adapted to sandy soils? Explain.
10. To what classes of crops are sandy soils best adapted?
11. What is meant by heavy clays?
12. Describe how heavy clay soils may be formed. Give examples.
13. Name some of the characteristics of clay.
14. Discuss methods of maintaining good tilth on heavy clay land.
15. Explain why grasses and cereals are best adapted to these soils.
16. Why are heavy soils particularly objectionable for the growing of potatoes?
17. Why do most crops on heavy clay soils respond well to the use of phosphate fertilizers?
18. Why do some clays contain more organic matter than others?
19. When a clay soil is black, does it necessarily mean that it is well supplied with available nitrogen? Explain.
20. Do clay soils ever require lime?
21. What are marsh soils, and how are they formed?
22. Distinguish between muck and peat soils.
23. What factors should govern the construction of open ditches?
24. What precaution should be taken in laying tile in a peat marsh?
25. What are the peculiarities of marsh soils as a class in regard to fertility?
26. Explain why some marsh soils are acid and others are not.
27. How may the fertilizer needs of marsh soil be best supplied?
28. In what ways is the looseness of marsh soils unfavorable to the growth of crops, and how may it be overcome in part?
29. What crops are especially well adapted to marsh soils, and why?

LESSON XI. SOIL ADAPTATION TO CROPS.

Relations between soils and crops (Ref. No. 4, pp. 291-306; or No. 10, pp. 232-256).—There are a number of important relations between the character of the soils and the crops to which they are adapted. The climate also has an important effect, not only directly on the crop, but indirectly through the soil. Certain crops require long growing seasons between frosts, and they are seriously injured by a freezing temperature. The amount of rainfall is likewise an important consideration. Some crops growing very early in the spring and maturing in the early summer require much less water than do those growing during the longer summer season when evaporation, not only from the plant itself, but also from the soil, is at the maximum. Moreover, there is an intimate relation between the water-holding capacity of the soil and the character of the rainfall upon crop production. Soils which have a fine texture and deep subsoil are able to retain nearly enough moisture from the early spring rains to mature crops growing through the summer, provided sufficient care is taken to develop a mulch so as to lessen the surface evaporation. Again, there is a close relation between the texture of the soil and the conditions affecting the quality of the crop, and also the use of tools both in planting and harvesting. All of these matters must be carefully considered. The following paragraphs are intended only as suggestions on some of the more important of these relations as they affect some of the more important crops. Crops may, for this purpose, be grouped into three classes, (1) tilled crops, (2) cereals, and (3) grasses and legumes.

SOILS ADAPTED TO TILLED CROPS.

While tilled crops, such as corn, potatoes, sugar beets, cabbage, etc., differ among themselves in many important respects, they are alike in that they permit tillage of the soil to kill weeds and for the development of a soil mulch to lessen evaporation of water. Most of them also grow through the long summer season, making a large growth, which requires abundant supplies of all the essential elements of plant food.

Corn (Ref. Nos. 7, p. 576; 10, p. 243).—Corn may be grown in any section having a season of 100 days free from frost, but the larger yielding varieties require 120 days, and a maximum growth of this crop occurs only in sections having relatively warm nights. Higher altitudes are therefore not suitable, since they are characterized by cool night temperatures. The larger quantity of water used by heavy crops of corn can be supplied only by soils having large water-holding capacity or in sections where the summer rainfall is relatively large. Hence the best results with this crop are secured on com-

paratively level alluvial soils, which are not so fine in texture as to make tillage for the development of good tilth and conservation of moisture impossible. Sandy loams, loams, and silt loams are therefore better than heavy clay soils. The large amount of nourishment required by this crop can be supplied only by soils having high natural fertility or by the use of fertilizers. The virgin fertility of the rich black prairie soils has proved sufficient to meet the demands of this crop for a number of years after being first broken, but in no case can undiminished yields be expected to continue indefinitely without the application of fertilizers.

The study of the root system of corn is interesting. (Ref. No. 2, pp. 215). As ordinarily planted in rows $3\frac{1}{2}$ feet apart in a deep permeable soil, the roots extend to a depth of 18 inches by the time the crop is $1\frac{1}{2}$ feet high and is about 6 weeks old. Even at this stage the roots meet between the rows so that the entire subsoil is occupied. When the corn has reached a height of 3 feet the roots often extend to a depth of about 24 inches.

Cotton (Ref. No. 7, pp. 695, 696).—Cotton requires approximately 130 days to reach maturity and so is confined practically to the region south of a line running from southern Virginia to northern Oklahoma. The lowland varieties of cotton require a longer season than do the upland varieties. The requirements of cotton for water and fertility are very similar to those of corn, and this crop gives good yields on heavy soils well supplied with organic matter in sections where the rainfall is not too large. This is especially true in Texas. In the Southeastern States, however, the most widely grown varieties give best results on sandy loam soils.

Tobacco (Ref. No. 7, pp. 699–701).—Tobacco is similar to corn and cotton in its fertility requirements, except that it uses somewhat less phosphorus than these crops. It requires large amounts of nitrogen and potassium and must grow rapidly and thoroughly cover the ground in order to develop the self-shading which is necessary to the fine texture of the leaf essential to the production of a good smoking flavor. For this reason the soil must be kept in the highest state of fertility, and there must always be an excess of the essential elements in available form beyond that needed to supply the actual requirements of the growing crop.

The texture of the soil also has an important influence on the quality of the tobacco leaf. The finer textured wrappers are grown only on loams and sandy loams, while the coarser textured fillers may be grown on heavier soils, which produce larger yields, though of a lower grade. Topography has an important bearing on the growth of tobacco, since it influences humidity and danger of storms to which this crop is especially subject. Shallow-dipping valleys in which the

humidity is higher than on hilltops and in which danger of storms is less are especially well suited for this crop.

Sugar beets (Ref. No. 7, pp. 606-608).—With reference to fertility, sugar beets have essentially the same requirements as corn, though it is important to recognize the fact that this crop requires a great deal of hand labor. A highly fertile soil, comparatively free from weeds, is therefore even more desirable for this crop than for corn or cotton. There is a close connection between the climate and the sugar content of the beet. The most favorable conditions are those of relatively cool nights and of very clear, bright weather, especially during the ripening period. These two conditions are combined in the North and in the western prairie States, where the altitude is such as to produce cool nights.

Potatoes (Ref. Nos. 7, pp. 598, 604; 10, p. 254).—While potatoes are similar to corn and sugar beets in their general requirements of plant food, their production on a large scale is chiefly controlled by conditions affecting: (1) Their quality and freedom from the diseases to which they are subject, and (2) the use of tools for planting and digging. The largest yields of this crop may be secured on relatively heavy soils which have high water-holding capacity and ordinarily greater fertility, but on these soils the crop is subject to diseases and can not be planted or harvested as readily as on the lighter sandy loams which permit the use of the digger and do not bake or crack so as to allow sunburn. Hence, this crop is best grown on relatively light soils. When grown on heavier soils and in a region of heavy summer precipitation a ridged system of culture is best, but on the lighter soils and wherever summer rainfall is not excessive flat culture is preferable.

Scab and other fungus diseases to which the potato is subject develop more often on soils of neutral or alkaline reaction than on those which are acid, and hence, as before stated, the use of lime for the correction of soil acidity is not desirable on the potato crop, or if used on land on which potatoes are to be grown it should be applied on the crops from one to three years before the potatoes are grown.

Cabbage and celery (Ref. No. 7, pp. 625, 628).—These crops are similar in that they require large amounts of nitrogen, potash, and water for their growth. Muck soils meet the requirements in regard to nitrogen and water and require chiefly the use of potash fertilizers to meet the demands of these crops.

Melons, cucumbers, tomatoes, etc. (Ref. No. 7, pp. 614-637).—These crops are similar, especially in that they require unusually warm soils and so are especially adapted to sandy loams. The fertility of these soils can be maintained only through the use of relatively large quantities of fertilizer, which should be applied in the form of organic matter, such as barnyard manure and dried blood, as far as possible.

SOILS ADAPTED TO CEREALS.

(Ref. No. 7, p. 574.)

The most important cereals are similar in regard to their root systems, which are much finer than those of crops which are commonly intertilled. They are also similar in that their growth takes place early in the season and they are therefore able to take advantage of the moisture which has accumulated during the winter. Hence they may be grown in sections of relatively low rainfall, in which the summer is quite dry.

Oats (Ref. Nos. 7, pp. 587-589; 10, p. 241).—Oats are especially adapted to a northern climate and have a relatively strong root system, going 50 per cent deeper than other grains. Varieties have been developed which are adapted to different types of soil. The Kherson or sixty-day oat, for instance, is especially well adapted to marsh land, because of its strong stem which prevents it from lodging on a soil on which crops are naturally very subject to that difficulty.

Rye (Ref. Nos. 7, pp. 585-587; 10, p. 243).—Rye has been developed chiefly in climates of relatively light rainfall, and this, together with the fact that it is sown in the fall and attains considerable root development then, permitting it to mature quickly the succeeding spring, makes it fairly profitable on sandy soils low in water-holding capacity and in sections of the country having a light rainfall.

Wheat (Ref. Nos. 7, pp. 581-585; 10, pp. 234-241).—On account of the fact that wheat has been more widely grown for human food and over a much larger part of the earth than other cereals, it has developed the power of adapting itself to a greater variety of conditions than other grains. It grows in countries with very hot climates as well as in almost the coldest climates permitting growth of agricultural crops. Some varieties will do well with very high rainfall, while others are adapted to regions of very low rainfall. While it can be grown on many different kinds of soil, wheat is best adapted to relatively close-textured soils, such as silt and clay loams.

SOILS ADAPTED TO GRASSES AND LEGUMES.

(Ref. No. 7, pp. 536-573.)

True grasses, especially those used for pasturage and hay, are characterized by very fine root systems. They differ also from most other cultivated plants in that they grow continuously through the entire growing season and therefore require a more uniform distribution of moisture than is essential to crops growing only early in the spring or during the midsummer period. The extremely fine root systems of these plants adapt them especially to clay soils, which they are able to permeate and from which they can extract the large supplies of moisture which these soils are able to hold.

Legumes, such as clovers, soy beans, and cowpeas, on account of their ability to secure nitrogen from the atmosphere, are of particular value for growth on soils low in organic matter. They include annuals and biennials of wide range of resistance to drought and frost, so that a selection can be made of those which are best adapted to almost any conditions, and every farmer should see to it that he has thoroughly mastered the growth of one or more legumes in such a way as to maintain the nitrogen and organic matter of his soil at its highest state.

EXERCISES, LESSON XI.

(a) Draw a map of the United States, or secure outline maps having State lines, then locate and label the important corn, wheat, potato, sweet potato, cotton, tobacco, and flax sections by States. Use the Yearbook of the Department of Agriculture for 1913 to select the States, as follows:

Corn.—Select five States having highest acreage, page 372.

Wheat.—Select five States having highest acreage, page 381.

Potatoes.—Select eight States having highest acreage, page 411.

Sweet potatoes.—Select six States having highest acreage, page 414.

Cotton.—Select six States having highest acreage, page 423.

Tobacco.—Select five States having highest acreage, page 428.

Flax.—Select five States having highest acreage, page 434.

(b) Discuss the relation of climate, soils, and rainfall in these sections to the various crops named. Consult this lesson, Ref. No. 7, pp. 574-710, and any good general cyclopedia.

REVIEW QUESTIONS, LESSON XI.

1. Name some of the factors which determine the adaptability of crops to soils.
2. Discuss the relation of corn growing to the climate conditions of the Mississippi Valley.
3. What influence has texture of the soil on the quality of tobacco?
4. Mention three conditions of soil or climate essential to success in raising sugar beets.
5. For what reasons are potatoes best grown on sandy loam soils?
6. Explain the relation between fungus diseases of potatoes and the chemical reaction of the soil.
7. What are the special requirements of cabbage and celery?
8. What conditions of soil are best adapted to the growing of melons and cucumbers?
9. Explain why grasses are able to grow better on heavy clay soils than root crops can.
10. On what principle does the classification of soils into grass soils, grain soils, and truck soils rest?

LESSON XII. CROP ROTATIONS AND SOIL FERTILITY.

(Ref. No. 4, pp. 273-283; or No. 6, pp. 356-372; or No. 7, pp. 505-507; or No. 10, pp. 298-300.)

Although it is easier to learn to grow one crop well than to learn to grow several crops well, nevertheless, there are distinct reasons why it is best to grow more than one crop on most farms. It permits a more economical and efficient use of labor; it involves less chance of failure, which may be entire in case of loss of a single crop grown;

it permits the growth of crops on different kinds of soils occurring on the farm; and, most important, it permits a cropping system whereby soil fertility may be improved.

Advantages of rotation to the soil.—The advantages of a rotation of crops or cropping systems in its relation to fertility are (1) it permits the use of manure on those crops to which it is best adapted; (2) it aids in preventing diseases or other unfavorable conditions which may develop on soil kept continuously in one crop; (3) it permits tillage calculated to improve the tilth; (4) it aids in the eradication of weeds; and (5) it permits the growth of crops which will result in an addition of humus and nitrogen to the soil.

We have already seen that raw manure can be used to much better advantage on certain crops, especially such rank-growing crops as corn, sugar beets, cabbage, and cotton, which permit inter-tillage, than on small grains or many of the vegetables.

The advantages of a rotation of crops in lessening diseases are becoming more and more apparent as our agriculture becomes more fixed. The growth of any cultivated plant on a given area or even in a given neighborhood continuously for a number of years is almost invariably followed by the appearance of some specific diseases or insect enemies, which are attached in one way or another to the soil on which the crop is grown. The development of the corn-root fungus, the cabbage diseases, the flax-wilt diseases, and many others which might be mentioned are evidences of this fact. While many of these diseases can be treated with specific remedies, applied to the seed before sowing or to the plant in the proper stage of development, it is nevertheless a very great aid in reducing difficulties of this kind to have the crop grown but one or two years on a given piece of land and then have it followed by other crops not subject to the same diseases.

Good tilth may be much more readily maintained on soils difficult to work by a rotation of crops than when the same crop is grown continuously. For example, the use of heavy clay land for meadow and pasture, in which the development of sod occurs makes it much easier to keep such soil in good tilth than when it is kept continuously in tilled crops.

A large part of the labor of land tillage is concerned in the eradication of weeds. A rotation of crops greatly aids in this matter. Some weeds are entirely unable to withstand the crowding of grasses, and the use of land as meadow and pasture will naturally kill them. Others, on the contrary, develop under these conditions and can be removed only when the land is in tilled crops which permit cultivation. The planning of any rotation must take into account the eradication of noxious weeds when these constitute a serious difficulty on the farm.

Probably the most important object of the rotation of crops on a large part of the best agricultural land of this country is concerned with the maintenance and increase of humus and vegetable matter in the soil. (Ref. No. 4, p. 275.) Increase of humus in the soil takes place when crops are grown which are not intertilled and have fine root systems permeating even compact soils. The use of land as meadow and pasture is, therefore, one of the most effective ways for adding to the humus content of the soil. If the meadow or pasture contains legumes, the nitrogen as well as the humus content is increased.

Planning the cropping system.—To gain the advantages mentioned above, a rotation of crops must be very carefully planned. The essential parts of the rotation consist in (1) intertilled crops, (2) grain crops, and (3) grass and legume crops to be used either as hay or pasture. But in working out the plan for rotation the farmer must consider not only the crops to be grown, but the relative yield of each, since it is necessary that the farm be laid out in fields of essentially uniform size. On an 80-acre dairy farm, for instance, the farmer might wish to grow corn, oats, or other grain, clover, and have some pasture. While the best division of the farm among these crops might be an even one, it is necessary to adjust the total yields of the several crops grown until the division of the farm into fields of equal size is practicable. It is possible, however, to grow any of these crops more than one year on the same piece of land in a single rotation, so that if it is desired to have more than one-fourth of the land in corn, that can be arranged by growing this crop two years in succession, or if more grain is desired the same method may be used. Again, a large number of farms include unimproved land, which can be used as permanent pasture but can not readily be brought into the rotation with other crops.

Relation of rotation to type of soil.—Each type of soil must be considered separately with reference to the rotations for which it is best adapted. (Ref. No. 7, p. 506.) On sandy soils short rotations give better results than long rotations. As far as practical, at least one-third or one-fourth of the soil of a sandy farm should be in a legume or other crop, part or all of which is to be turned under for green-manuring purposes. On one of the best potato farms in Wisconsin the following rotation is practiced: First, potatoes in which rye is sown ahead of the potato digging, so that it makes a good start in the fall, and then timothy. Clover is sown and dragged in the following spring. This gives a 3-year rotation of potatoes, rye, and clover. Practically all of the clover is plowed under as a green-manure crop. In this way the soil is kept well supplied with active organic matter, and the sand is protected from blowing by the rye in the fall and spring.

On heavier soils, where grain and stock raising is practiced, a longer rotation is usually desirable, especially if some of the cultivated land is also to be used for pasture. A 6-year rotation can then be worked out, such as the following: Corn, wheat, oats, clover, timothy, and pasture, or it can be shortened to five years by omitting either one of the grains or the pasture year.

Rotation for different types of soil on the same farm.—Over a considerable part of the United States there is such a variation in soils within short distances that the relation of one type of soil to the other must be fully considered. When a farm includes sand and marsh soils which have been drained and brought under cultivation, all of the manure should be used on the sandy soil, since the marsh soil does not need nitrogen, and can be kept in a high state of fertility through the use of moderate quantities of commercial fertilizers containing potassium and phosphorus, thereby making it possible to keep the fertility of the whole farm in a high state. The same method may be used when the farm includes clay and marsh soils. In such cases it may be necessary to develop two or more systems of rotations on a single farm. All of these matters must of course be worked out with reference to each particular case, and the success of the farmer depends to a considerable extent on his judgment in working out logical systems of cropping adapted to his soil conditions as well as to his market and other factors affecting his work.

Rotation systems for permanent fertility (Ref. No. 5, Chaps. XV and XVI, pp. 226–235).—After all, it must be recognized that the most important problem in any system of farming is so to conduct the cropping and the disposition of the crops that the fertility of the soil shall not alone be maintained, but that it shall be constantly built up in the best and most profitable manner. Herein lies one of the most vital parts of good farm management. The somewhat prevalent idea among farmers that simply rotating crops will improve, or even maintain, the fertility of soil is without a safe foundation. It is true, for reasons stated in the beginning of this lesson, that far better results in cropping will be realized from a well-planned rotation than from a single-crop system. But actually to build up the fertility of a soil one should first understand what elements of plant food are low in the soil, then the cropping system, the type of farming, the building up of humus and mineral elements through manures and fertilizers, and the physical management of the soil should all be so studied and planned that gradual soil improvement will result. The management necessary to attain this end will vary, of course, with the system of farming practiced.

In vegetable gardening, manure from cities can usually be secured in quantity, and the soil can be improved while profits are realized from the crops by the purchase of both stable manure and com-

mercial fertilizers. In fruit farming, it is generally necessary for soil improvement to grow legume crops to return to the soil as well as to add the mineral elements which are low in the soil by using fertilizers. In grain farming, if fertility is to be maintained or increased, the grain, including small seed, may be sold, but all roughage, including cornstalks and straw from grain and seed, should be returned to the soil; besides, a legume crop like red clover should be grown once in three or four years as a green manure to furnish vegetable matter and nitrogen to the soil, while mineral elements not plentiful in the soil should be regularly added to provide for what is removed from the sale of grain. It should be remembered also that phosphorus is removed from the farm in large quantity in grain farming. In live-stock farming, where the manure is well cared for and returned to the soil without much loss, the humus and nitrogen content of the soil can be built up where sufficient leguminous crops are grown in the rotation to furnish the feed of this kind necessary for the best results with the live stock. However, it will still be necessary to return some mineral elements, especially phosphorus, in order to increase the fertility of the soil.

EXERCISES, LESSON XII.

ROTATION PROBLEMS.

1. Plan a system of crop rotation on an 80-acre sandy farm, potatoes being the main crop.
2. Plan a rotation for farming on a 120-acre sandy farm. The following crops are to be grown each year as far as possible: Corn, 25 acres; rye, 12 acres; oats, 15 acres; clover, 25 acres; alfalfa, 10 acres; potatoes, 4 acres; tomatoes, 2 acres; and melons, 2 acres. Five acres are allowed for buildings, etc., and 20 acres for pasture.
3. Describe a plan for treating the soil in problem 2—use of manure (200 tons), commercial fertilizers, liming, and inoculation.
4. Suppose the sand on one of the forties in problem 2 is subject to blowing by the wind, will that make any change in the plan for rotation? Work out a plan of crop rotation under these conditions.
5. Suggest a plan for rotation on a sandy soil on which potatoes, tomatoes, melons, and onions are the principal market crops.
6. Plan a rotation on a southern sandy plantation of 200 acres where peanuts are an important crop. Other crops grown are cotton and corn. (Ref. No. 7, pp. 695-710.)
7. A man owns the W. $\frac{1}{2}$ and the SE. $\frac{1}{4}$ of the SW. $\frac{1}{4}$ of a section of land. Locate this land in the section.
8. All of this land in problem 7 is level and under cultivation. Each year he raises 40 acres of corn, 20 acres of clover, 20 acres of timothy, and 40 acres of oats in a 3-year rotation. Outline his system of rotation.
9. A farmer has a farm including the SE. $\frac{1}{4}$ of the NW. $\frac{1}{4}$; the SW. $\frac{1}{4}$ of the NE. $\frac{1}{4}$; the NW. $\frac{1}{4}$ of the SE. $\frac{1}{4}$; and the NE. $\frac{1}{4}$ of the SW. $\frac{1}{4}$ of a section. His farm buildings, orchard, and garden take out 5 acres in the NW. corner of the NW. $\frac{1}{4}$ of the SE. $\frac{1}{4}$. This land is all level, silt loam. In order to meet his requirements he wants to raise each year 40 acres of corn, 40 acres of hay (30 of clover and 10 of timothy), 30 acres of oats, 10 acres of barley, 5 acres of potatoes, and 30 acres of pasture. Plan a system of crop rotation.

10. If 300 tons of manure are produced on the farm annually, in problem 8, how can this manure be most economically used?

11. A man owns the W. $\frac{1}{2}$ of the NW. $\frac{1}{4}$ of a section of land. On the north end 20 acres are taken out of the crop-producing portion of the farm on account of woodlot, farm buildings, and railroad right of way. Each year this man raises 20 acres of corn, 20 acres of oats, and 20 acres of hay (5 of alfalfa and 15 of a mixture of clover and a little timothy). A 3-year rotation is practiced, with the exception of alfalfa, which is left four years. Draw a diagram showing how this man rotates his crops.

12. A farm located in the S. $\frac{1}{2}$ and the NE. $\frac{1}{4}$ of the SE. $\frac{1}{4}$ of a section contains 20 acres woodlot in the W. half of the NE. $\frac{1}{4}$, 10 acres of hillside subject to erosion in the NE. $\frac{1}{4}$ of the NE. $\frac{1}{4}$, and 20 acres of acid sandy soil at the west end of the S. $\frac{1}{2}$. Five acres in the SE. corner of the farm are taken out for buildings. Plan a system, or systems, of rotation on this farm when the following crops are to be raised each year as far as possible: 30 acres of corn, 20 acres of oats, 10 acres of barley, 10 acres of alfalfa, 15 acres of clover, and 30 acres of pasture, including woodlot.

REVIEW QUESTIONS, LESSON XII.

1. Give specific reasons why it is best to grow more than one crop on a farm.
2. Name five advantages derived from a crop rotation.
3. What is understood by tilled crops? Intertilled crops?
4. Explain how grasses are better adapted to humus formation than cultivated crops.
5. Name the essential parts of a rotation.
6. What determines largely the kind of rotation a farmer may practice?
7. Discuss the rotation best suited to a sandy farm.
8. Suggest a 6-year rotation for a dairy farm. A 5-year rotation.
9. On a farm consisting of sand and marsh, where can manure be used to best advantage? Why?
10. Discuss the relation of different types of soils in a farm to crop rotations.
11. Outline a cropping system and a plan of fertilization for grain farming whereby the fertility of the soil of the farm may be maintained or increased.
12. Compare grain farming with live-stock farming from the soil-fertility standpoint.
13. What is the most important problem in connection with permanent agriculture.
14. Are you now able to figure out accurately a profitable system of cropping and fertilization whereby the fertility of your farm will gradually be increased?



APPENDIX.

REFERENCE BOOKS.

The publications here listed are specifically referred to in the text and must be consulted in order to obtain the information purposely omitted in the bulletin because of want of space. This library of reference books will be supplied by the State agricultural colleges and loaned by them as a unit to each class.

1. First Principles of Soil Fertility. Alfred Vivian, 1906.
2. The Soil. F. H. King. 1896.
3. Soils, Their Properties and Management. T. L. Lyon, E. O. Fippin, and H. O. Buckman, 1915.
4. Soils and Fertilizers. Harry Snyder, 1908, 3. ed.
5. Soil Fertility and Permanent Agriculture. C. G. Hopkins. 1910.
6. The Fertility of the Land. I. P. Roberts. 1909, 3. ed.
7. Fertilizers and Crops. L. L. Van Slyke. 1912.
8. Practical Farm Drainage. C. G. Elliott. 1908, 2. ed.
9. Chemistry and its Relations to Daily Life. Louis Kahlenberg and E. B. Hart. 1913.
10. Dry Farming. J. A. Widtsoe. 1913.
11. Yearbook of the United States Department of Agriculture. 1913.
12. Manures and Fertilizers. H. J. Wheeler. 1913.
13. Soils. E. W. Hilgard. 1910. To be included when classes are conducted in arid regions.
Any unabridged dictionary.

LIST OF APPARATUS AND SUPPLIES REQUIRED.

APPARATUS.

- | | |
|---|---|
| 12 Coddington or other cheap hand lenses. | 6 feet small-sized glass tubing. |
| 12 long pickle bottles with corks. | 3 three-inch unglazed tile. |
| 6 wide-mouthed bottles with corks. | 4 wooden boxes, 1 foot square and 4 inches deep. |
| 24 one-inch cubes. | 6 small Fahrenheit thermometers. |
| 6 two-gallon crocks or jars. | 1 marble slab, 1 foot square, polished on both sides. |
| 6 one-pint glass fruit jars. | 4 three-gallon crocks. |
| 6 jelly glasses. | 24 outline maps of the United States. |
| 1 balance with weights. | 6 porcelain dishes. |
| 12 one-pound baking-powder cans. | 12 one-hole stoppers. |
| 2 measures graduated for cubic inches. | 6 feet rubber tubing. |
| 2 small mortars and pestles. | 1 set of soil sieves. |
| 6 one-quart glass fruit jars. | Cheesecloth. |
| 6 tin cups. | 1 package small needles. |
| 6 pie tins. | |
| 6 shallow dishes (saucers). | |
| 6 pieces of $\frac{3}{4}$ -inch or 1-inch glass tubing (2 feet long). | |

SUPPLIES.

Specimens of common rocks as follows:

Granite, schist, shale, slate, limestone,
marble, sandstone, quartzite, feldspar,
hornblende, quartz, black and white
mica, calcite, gypsum.
1 pound paraffin.
4 ounces muriatic acid.
1 quart powdered limestone.
Several small pieces limestone.
1 quart sodium nitrate.
1 quart muriate of potash.
1 quart sulphate of potash.
1 quart ammonium sulphate.

1 quart kainit.
1 quart acid phosphate.
1 quart rock phosphate.
1 quart bone meal.
4 ounces ammonium carbonate.
4 ounces marble dust.
6 packages each of red and blue litmus
paper.
1 pound lump sugar.
1 pound powdered sugar.
6 sticks sodium hydroxid.
1 quart burnt lime.
1 stick sealing wax.

NOTE.—The apparatus and supplies have been estimated for a class of twelve. Ordinarily two people will work together in laboratory practice, and the quantity of apparatus and supplies may be varied to suit the size of the class. The different soils needed should either be furnished as a part of the supplies, or else arrangements must be made for the class to secure and dry them before the work of the course is begun.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 356

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief



Washington, D. C.

PROFESSIONAL PAPER

March 7, 1916

MILK AND CREAM CONTESTS.

By ERNEST KELLY, *in Charge of Market Milk Investigations*, and L. B. COOK and J. A. GAMBLE, *Market Milk Specialists, Dairy Division.*

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INTRODUCTION.

Among those engaged in the production of sanitary milk there is an axiom that "education accomplishes more than legislation." To a certain point law can be applied; glaringly insanitary conditions and willful wrongdoing can be severely dealt with, but after a certain degree of cleanliness has been reached much of the subsequent improvement must be based upon the incentive offered the producers to go to more trouble and expense to improve the product.

For the purpose of teaching producers the fundamentals of clean-milk production, as well as offering them an incentive, the plan of holding milk and cream contests was devised. On February 14-24, 1906, during the National Dairy Show in Chicago, Ill., the first milk and cream contest was held. A tentative score card was devised for rating the samples, and from time to time, as defects were demonstrated, this card has been modified. From the beginning rapid progress has been made and in the nine years from February, 1906, to February, 1915, 87 such contests have been judged by members of the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture.

In March, 1907, with the belief that these contests would aid greatly in improving the milk supply of a city, the first city milk

NOTE.—This bulletin is of interest to dairymen generally, and especially to those who are engaged in improving the output of their establishments.

contest was held in Cleveland, Ohio. The Dairy Division, by supplying judges and lecturers, cooperated with the chamber of commerce of that city. Since the Cleveland exhibit several other cities have seen the value of these contests and have conducted similar enterprises. Usually the chamber of commerce arranges for the exhibit by securing a meeting place, furnishing the prizes, and sending advertising matter to the dairymen and consumers. Among the cities that have held such contests are Cleveland, Columbus, Toledo, Cincinnati, and Dayton, Ohio; Pittsburgh and Philadelphia, Pa.; Detroit, Muskegon, Grand Rapids, and Pontiac, Mich.; Jacksonville and Tampa, Fla.; South Bend, Ind.; Cumberland, Md., and Rochester, N. Y. The exhibits have not only increased in number, but have grown greatly in size.

NATIONAL CONTESTS.

The contest for milk and cream producers annually held in connection with the National Dairy Show has grown remarkably since the first exhibit in 1906. Such a national contest brings together a set of unusually fine samples, from all parts of the country. From the data on the production of these samples much useful and interesting information can be obtained. The two most recent contests in connection with the National Dairy Show, in the years 1913 and 1914, brought out 217 entries, from 20 States and from Canada. The following-named States were represented, the figure after each State indicating the number of samples submitted: Wisconsin, 6; Ohio, 10; Illinois, 9; Michigan, 56; Pennsylvania, 38; Massachusetts, 12; New Hampshire, 3; Virginia, 1; New York, 10; Indiana, 2; Missouri, 1; Kentucky, 3; Washington, 37; Iowa, 1; New Jersey, 13; Texas, 1; West Virginia, 2; Connecticut, 3; Maryland, 6; Minnesota, 1. Two entries were from Canada. Thus samples were sent from as far west as the Pacific States, from as far east as the New England States, from as far south as Texas, and from as far north as Canada.

The form of entry for the National Dairy Show is presented herewith:

[National Dairy Show Association. Milk and Cream Show. Chicago, Ill., Oct. 23 to Nov. 1, 1913, under the direction of the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture.]

[Only this official entry blank will be accepted.]

CLASS 209, MARKET MILK.

Gentlemen: Please enter for me 4 pints of market milk in competition for prizes offered by the National Dairy Show, in accordance with the conditions herein prescribed.

.....Proprietor.
.....Manager.

P. O. Address

Date 1913.

(1) Competition in milk and cream department is open to all milk and cream producers in the United States and Canada.

(2) Producers of market milk may compete in both market milk and market cream classes.

(3) Producers of milk can make but one entry in any one class.

(4) Producers of certified milk are barred from competition in market milk and market cream classes. All samples of certified milk must be accompanied by a certificate issued by a medical milk commission.

(5) Entries in milk classes consist of 4 pints of milk in pint bottles.

(6) Entries in cream classes consist of four $\frac{1}{2}$ pints of cream in $\frac{1}{2}$ -pint bottles.

(7) All entries of milk and cream after scoring become the property of the United States Department of Agriculture.

(8) No exhibitor will be entitled to a medal or diploma who does not make answer to each question, sign declaration, and forward this official entry blank to Ernest Kelly, superintendent of milk and cream exhibits, National Dairy Show, 817 Exchange Avenue, Chicago, Ill.

HOW TO COMPETE.

Milk entered to compete for prizes must be sent by express or otherwise from station nearest the producer direct to Ernest Kelly, superintendent milk and cream exhibit, care of Armour & Co., Chicago, butter and egg storage department.

EXPRESS CHARGES ON EXHIBITS MUST BE PAID TO DESTINATION.

Bottles must be carefully packed, caps should be sealed, making bottle air-tight, and both top of bottle and cap should be protected with paper, metal, or other material and all covered with crushed ice sufficient to maintain a low temperature during transportation.

The package should be plainly addressed on outside. A card should also be tacked on box, on inside, giving plainly sender's name and address so as to avoid mistakes in identifying packages.

In order that all milk entered by exhibitors may be of the same age when scored, it is hereby specified that it shall be produced on Thursday, October 16, and shipped and delivered to express company at once. This is necessary for perfectly fair competition.

A representative of the Department of Agriculture will be in Chicago to take charge of the milk on its arrival and see that it is properly cared for.

Whenever possible, entries should be shipped in cases which need not be returned. The show association does not guarantee the return of shipping cases, but will endeavor to have them returned to the proper owner at the owner's expense when properly requested.

QUESTIONS TO BE ANSWERED IN DETAIL BY EXHIBITORS OF MILK.

1. On what day and hour was the sample of milk entered in this show drawn?.....
2. How many cows contributed to the sample of milk entered?
3. How many cows in your herd are now giving milk?
4. How long since the cows contributing to the sample of milk freshened? (Average time)
5. Are the cows supplying this sample grades or pure bred?.....
If pure bred, give name of breed
6. What kind and amount of feed was given cows daily during the week preceding the production of this sample of milk?
7. Were cows cleaned previous to milking? If so, describe method of cleaning.....

8. Were cows in stable or out of doors when the sample of milk was drawn?.....
If in stable, how was stable cared for?.....
9. What precautions were taken by the milkers as regards cleanliness of clothing and hands?
10. How many milkers were engaged in milking the sample entered?.....
11. What kind of milk pail was used—narrow or wide top?
12. How were pails cleaned previous to use?.....
13. Was milk drawn from the cow direct into the pail or through cloth cover or cotton fiber?
14. What method of straining milk, if any, was followed?
15. How long after milk was drawn from cows before it was cooled?.....
16. Describe milk cooler, if any was used.
17. How was milk cooler prepared for use?
18. To what temperature was milk cooled?
19. How were bottles and caps prepared for use?
20. What bottling process or what method of bottling was followed?
21. How was milk cared for after bottling and previous to shipment?
22. Give date or hour when milk was (or will be) shipped.....
23. Do you wish shipping case returned at your expense?.....
24. Have you previously exhibited milk or cream at any local, State, or National show?
25. Give name and address of medical milk commission certifying to your product?

Remarks:

I,, do hereby declare each and every statement in answer to the above questions to be absolutely true. I do furthermore declare that the milk submitted by me in this contest is the pure natural product, free from preservatives, and that it has not been heated or changed in any way.

..... Proprietor.
..... Manager.

HOW CONTESTS ARE CONDUCTED.

In preparing for a milk and cream exhibit the persons who have charge of the contest usually send out preliminary notices to the dairymen, stating that a contest will be held at a certain time and place and urging them to prepare to enter samples. Samples should be produced about six days before the meeting; this gives ample time for announcing results and awarding prizes, and affords an opportunity for contestants to discuss their scores with the judges. Later, entry blanks, such as shown above, are sent out. The filling out and returning of these blanks is made a prerequisite to the entering of samples of milk or cream in the contest. Usually there are several classes for which prizes are offered, such as certified milk, market milk, market cream, and pasteurized milk.

Certified milk and cream must be produced under the direction of a medical milk commission and bear the proper stamp of certification. Market milk and cream classes consist of those samples which are not eligible to compete as certified. All samples in the market and certified classes must be free from preservatives. Producers of

certified milk or cream are usually prohibited from entering any samples in the market classes.

MANAGEMENT OF THE SAMPLES.

There are no restrictions placed on the dairymen as to the production of the samples for the contest. The answers to questions on the entry blank show that many methods of milking are pursued. On some farms the cows are milked in the barn; at other places they are milked in the pasture or feed lot. Various methods of cleaning the cows are resorted to, and the milk is handled in a varied number of ways after it is drawn from the cow.

All the samples of milk that are entered in a contest must be produced on the same day. This makes all the samples the same age when they are scored. After the milk is bottled, it is packed in a shipping case and surrounded with ice so that it will be in the best possible condition when it arrives at the place of exhibition. Mixing salt with the ice may cause the samples to freeze.

The samples should be consigned to some cold-storage warehouse in the city where the exhibit is to be held, and upon their arrival put immediately into a cold room. In each entry should be four bottles, one for chemical analysis, one for bacteriological examination, one for judging flavor, odor, sediment, and appearance, and one to be placed on exhibition. When all these samples have arrived, the four bottles in each entry should be given a number, preferably on a tag put around the neck of each bottle. The bottles, bearing simply the number, are submitted to the judges, and the scores are all made by numbers instead of by the names of the dairies or of the owners.

It will be noticed on page 15 that some contests are tabulated separately. These contests were held under somewhat different regulations. Instead of allowing the dairyman to submit a sample of milk produced in any way, the samples, at irregular intervals through one entire month or more, were taken from the regular supply, as it was delivered. It was believed by those in charge of these contests that such a procedure would give a more definite idea of the average milk furnished by the dairymen and would also have the advantage of continuing a supply of high-grade milk from all the dairies entered.

Two objections to this method have been raised by some authorities. First, the taking of samples, through an extended period and at times unknown to the dairyman, is the legitimate duty of any health department; therefore a contest conducted in this way is very liable to confuse the dairymen as to the distinction between health-department work and milk exhibits. The second objection is the more potent one. Under the usual procedure the dairyman knows

just when and how the milk submitted to a contest is produced. At the time of milking he has to answer questions as to all the details of the process, so that he has a record of the condition of the cows, the feed, the cleanliness of his utensils, etc. Then, when he receives his score card and observes, for instance, that he has received a cut on flavor, he can go over the various details of the production of that milk and perhaps find the method which caused the trouble. When the samples are taken at times unknown to the dairyman, the direct educational value is lost to a certain degree. The dairymen, unless they have kept a complete diary of all methods and operations during the entire month, do not know until sometime afterwards when the samples were taken and have no means of knowing the conditions that prevailed when the milk was drawn.

On the other hand it has been argued by some that the score on a sample of milk submitted by a dairyman is not a correct indicator of the average product handled by that man. For instance, a man may ordinarily have a very mediocre supply of milk but by special efforts he may produce a very high-scoring sample for competition. No claims, however, should be made at the milk exhibits by those in charge that a high-scoring sample indicates that the exhibitor has an average supply of the same high quality. It is thought, moreover, that a man who learns the principles of clean milk production well enough to produce one sample of high-scoring milk is much more likely to put those principles into general practice than a man who has not studied the principles at all. Excellent results, however, have been obtained in the collected-sample contests.

SOME EXAMPLES OF PACKING.

Much ingenuity has been shown in shipping milk to some of the shows. One firm in Canada made a large box about 4 feet square, the sides, top, and bottom of which were made of thick cork. The whole was then covered with a preparation of tar to make it waterproof, and the bottles of milk were placed in a rack inside and the box filled with ice. The whole was then crated to prevent injury to the cork-board box. The cork was intended to serve as an insulation and to keep the ice from melting so rapidly.

In 1911 one Colorado dairy sent to the National Dairy Show milk which was shipped in a specially constructed crate made as follows: A galvanized cylinder, fastened at the bottom in a galvanized-iron box, was made for each bottle of milk or cream. The bottles of milk or cream were set down in the cylinders and a tightly fitting cover placed over the top of each one. Then the space surrounding each cylinder inside the galvanized-iron box was filled with crushed ice.

So much interest in proper refrigeration of the samples has been manifested that exhibitions as far away as Seattle, Wash., have sent a man with the exhibit to re-ice it whenever necessary upon the journey.

METHOD OF SCORING THE EXHIBITS.

The samples are scored for bacteria, flavor and odor, visible dirt, fat, solids not fat, acidity, and the appearance of the bottle and cap. Cream is scored on the same basis as milk, except that no score is given for solids not fat, the total of 20 points under chemical composition being given solely to fat.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
DAIRY DIVISION.

SCORE CARD FOR MILK.

Place.....

Class..... Exhibit No.....

Item.	Perfect score.	Score allowed.	Remarks.
Bacteria.....	35	.....	Bacteria found per cubic centimeter.....
Flavor and odor.....	25	.....	Cowy, bitter, feed, flat, strong.....
Visible dirt.....	10	.....	.....
Fat.....	10	.....	Per cent found.....
Solids not fat.....	10	.....	Per cent found.....
Acidity.....	5	.....	Per cent found.....
Bottle and cap.....	5	.....	{Cap.....
			{Bottle.....
Total.....	100	.....	

Exhibitor.....

Address.....

(Signed).....

Date....., 191

Judge.

D. D. No. 452.

[OVER.]

DIRECTIONS FOR SCORING.

BACTERIA PER CUBIC CENTIMETER—PERFECT SCORE, 35.

	Points.		Points.
Under 500.....	35.0	25,001-30,000.....	29.0
500-1,000.....	34.9	30,001-35,000.....	28.0
1,001-1,500.....	34.8	35,001-40,000.....	27.0
1,501-2,000.....	34.7	40,001-45,000.....	26.0
2,001-2,500.....	34.6	45,001-50,000.....	25.0
2,501-3,000.....	34.5	50,001-55,000.....	24.0
3,001-3,500.....	34.4	55,001-60,000.....	23.0
3,501-4,000.....	34.3	60,001-65,000.....	22.0
4,001-5,000.....	34.0	65,001-70,000.....	21.0
5,001-6,000.....	33.8	70,001-75,000.....	20.0
6,001-7,000.....	33.6	75,001-80,000.....	19.0
7,001-8,000.....	33.4	80,001-85,000.....	18.0
8,001-9,000.....	33.2	85,001-90,000.....	17.0
9,001-10,000.....	33.0	90,001-95,000.....	16.0
10,001-11,000.....	32.8	95,001-100,000.....	15.0
11,001-12,000.....	32.6	100,001-120,000.....	12.5
12,001-13,000.....	32.4	102,001-140,000.....	10.0
13,001-14,000.....	32.2	140,001-160,000.....	7.5
14,001-15,000.....	32.0	160,001-180,000.....	5.0
15,001-20,000.....	31.0	180,001-200,000.....	2.5
20,001-25,000.....	30.0	Above 200,000.....	0.0

NOTE.—When the number of bacteria per cubic centimeter exceeds the local limit the score shall be 0.

FLAVOR AND ODOR—PERFECT SCORE, 25.

Deductions for disagreeable or foreign odor or flavor should be made according to conditions found. When possible to recognize the cause of the difficulty it should be described under Remarks.

VISIBLE DIRT—PERFECT SCORE, 10.

Examination for visible dirt should be made only after the milk has stood for some time undisturbed in any way. Raise the bottle carefully in its natural, upright position, without tipping, until higher than the head. Observe the bottom of the milk with the naked eye or by the aid of a reading glass. The presence of the slightest movable speck makes a perfect score impossible. Further deductions should be made according to the amount of dirt found. When possible the nature of the dirt should be described under Remarks.

FAT IN MILK—PERFECT SCORE, 10.

	Points.		Points.
4.0 per cent and over.....	10	3.2 per cent.....	6
3.9 per cent.....	9.8	3.1 per cent.....	5
3.8 per cent.....	9.6	3.0 per cent.....	4
3.7 per cent.....	9.4	2.9 per cent.....	3
3.6 per cent.....	9.2	2.8 per cent.....	2
3.5 per cent.....	9	2.7 per cent.....	1
3.4 per cent.....	8	Less than 2.7 per cent.....	0
3.3 per cent.....	7		

NOTE.—When the per cent of fat is less than the local legal limit the score should be 0.

SOLIDS NOT FAT—PERFECT SCORE, 10.

	Points.		Points.
8.7 per cent and over.....	10	8.1 per cent.....	4
8.6 per cent.....	9	8.0 per cent.....	3
8.5 per cent.....	8	7.9 per cent.....	2
8.4 per cent.....	7	7.8 per cent.....	1
8.3 per cent.....	6	Less than 7.8 per cent.....	0
8.2 per cent.....	5		

NOTE.—When the per cent of solids not fat is less than the local legal limit the score shall be 0.

ACIDITY—PERFECT SCORE, 5.

	Points.		Points.
0.2 per cent and less.....	5	0.23 per cent.....	2
0.21 per cent.....	4	0.24 per cent.....	1
0.22 per cent.....	3	Over 0.24 per cent.....	0

BOTTLE AND CAP—PERFECT SCORE, 5.

Bottles should be made of clear glass and free from attached metal parts. Caps should be sealed in their place with hot paraffin, or both cap and top of bottle covered with parchment paper or other protection against water and dirt. Deduct for tinted glass, attached metal parts, unprotected or leaky caps, partially filled bottles, or other conditions permitting contamination of milk or detracting from the appearance of the package.

NOTE.—The card shown above was adopted in April, 1915, and is more nearly uniform in regard to its bacterial ratings than the old one. This one was not used in any of the contests mentioned in this bulletin, and is the third form adopted by the Dairy Division.

BACTERIA.

The samples are all plated for bacteriological examination on the same day. Standard methods of plating on agar are used, and the samples are incubated for 48 hours. In milk-contest work the dilutions used are 1 to 100 and 1 to 1,000 which give results close enough for such work. Any sample having fewer than 500 bacteria per cubic centimeter receives a perfect score, while any sample having more than 200,000 bacteria per cubic centimeter receives a zero. No attempt is made to differentiate between the kinds of bacteria present, only a quantitative analysis being made. It is a well-established principle that in the production of market milk all kinds of bacteria are to be excluded, so the awards are made on the basis of freedom from bacteria of any kind.

As bacteria in milk are extremely undesirable, both from a health as well as from economic standpoint, the greatest weight on the score card is given to freedom from bacterial contamination, 35 out of 100 points being allowed for this item.

FLAVOR AND ODOR.

While not so important as bacteria in their relation to public health, the flavor and the odor of dairy products considerably influence their commercial value. If consumers are served with an unpleasantly flavored milk, they will either use less of it or will seek some other dealer whose products are more acceptable. The most common "off flavors" and odors found in contest milk and cream are those produced by certain feeds and by the absorption of foul odors from the stable air. These defects will be considered more fully later in this bulletin.

In scoring, it is best to allow the samples to stand for a short while in a warm room, as undesirable flavors and odors are more easily detected if the milk is slightly warm. So far as possible, the room where the scoring is done should be free from any odors. The milk should be mixed as much as possible before the cap is removed. When the cap is removed about half the contents of the bottle should be poured into a clean receptacle; by quickly placing the nose over the mouth of the bottle any odor present can be detected.

Flavors, are, of course, scored by tasting the sample; if the flavor is very bad it can usually be definitely classified, but often the flavor is so slight or indistinct that it can not be traced with certainty. Even though this be the case, an experienced judge of milk is able to score the flavor of the product very accurately. Flavor and odor are allowed 25 points out of 100.

VISIBLE DIRT.

An appreciable amount of sediment in the bottom of a bottle of milk is a mute indication of carelessness between the cow and the consumer. Freedom from visible dirt does not necessarily mean that the milk is clean, but the presence of sediment does mean that not only was dirt allowed to fall into the milk, but that not even care enough was taken to strain it out.

To score perfect on this point, the judge must be unable to find so much as a single movable speck in the milk as determined by examining the bottom of the bottle. Very few samples have been scored perfect on this point, while some, on account of an extremely heavy precipitate of manure, dust, sand, cow hairs, or chaff, have been marked as low as zero.

Before scoring, the bottles should be allowed to stand undisturbed for some time to allow any sediment to settle. Then the bottle should be carefully raised without tipping and the bottom examined. An electric bulb with a long cord is a great aid in this work, as the light can be held close to the bottle. A maximum of 10 points out of 100 is allowed for freedom from visible dirt.

FAT AND SOLIDS NOT FAT.

The solids in milk are apportioned 20 points out of 100, 10 for fat and 10 for solids not fat; 4 per cent of fat and 8.7 per cent of solids not fat are minimums for which a perfect score is given. In the case of cream all 20 points are given to the fat content, 20 per cent or more being considered a perfect score. If the sample of milk or cream contains less than the legal standard, a zero is given on the score card.

The fat is determined by the Babcock method, while the solids not fat are calculated by the formula $\frac{L+F}{4}$. In this formula L

stands for the corrected Quevenne lactometer reading and F represents the fat. As an illustration of this formula, let us suppose that the fat test is 4 per cent and the corrected lactometer reading is 32.

Then, $\frac{32+4}{4} = \frac{36}{4} = 9$. Hence, the solids not fat equal 9 per cent.

ACIDITY.

The acidity is allowed 5 points out of 100. Phenolphthalein is used as an indicator, and the milk is titrated with tenth-normal sodium hydroxid. The results are reduced to percentages and the scores allowed according to the scale on the score card. As 0.2 per cent is considered the danger line in commercial milk and cream, no sample containing more than that amount of acidity is given a perfect score. While such milk may taste perfectly sweet, it has been found that it is usually unsafe to use it on account of the fact that it is apt to turn sour very quickly.

BOTTLE AND CAP.

The general appearance of the sample is considered of importance enough to demand an allowance of the remaining 5 points out of the 100. Samples should all be submitted in regulation milk bottles, and the mouth of the bottle should be thoroughly protected from dust, dirty water, etc. Deductions should be made for dirty or chipped bottles, or for flaws or other imperfections in the glass; for metal parts, especially such as come in direct contact with the milk, slight cuts should be made in the score. Caps should be sealed in place with hot paraffin, or both cap and top of bottle covered with parchment paper or other protection from water and dirt. It very often happens that the caps are hastily placed in the bottles, or are not of the proper size. This should be penalized, as it results in leakage from the bottles as well as permitting dirty ice water, etc., to seep into them.

Bottles should be filled so that there will be no room for churning during transit. Deductions should be made for violations of this rule.

EDUCATIONAL FEATURES.

Whenever milk and cream contests are held, it is desirable to have in connection therewith a meeting or a series of meetings at which the subject of clean milk production is thoroughly discussed. Usually at least two meetings are held, one for the producers and the other for consumers. At the producers' meeting the technical side of clean milk production is taken up and the dairymen are shown how they can improve the quality of their product. Comments are made on the samples entered in the competition, and remedies for the defects are suggested. At the consumers' meeting great stress is laid on the fact that clean milk is more difficult and expensive to produce than dirty milk, and an effort is made to educate the consumer to the point where he will be willing to pay an increased price for a safer and more wholesome article of food. Instruction is given to city milk consum-

ers as to the proper care of milk in the home after it is delivered to them by the producer. These lectures are very often illustrated with stereopticon slides; also moving pictures illustrative of good and bad methods on the dairy farms are sometimes shown.

LIST OF EXHIBITIONS.

The statements following show the most important facts relating to all the competitive exhibitions so far held in cooperation with the Dairy Division.

List of milk and cream contests held in cooperation with the Dairy Division, using the first score card.

Name and place.	Date.	Product.	Number of entries.	Average score.
National Dairy Show, Chicago, Ill.....	Feb. 15, 1906.	Market milk.....	23	89.70
		Market cream.....	14	93.60
		Certified milk.....	8	94.80
Granite State Dairymen's Association, Peterboro, N. H.....	Dec. 6-7, 1906.	Market milk.....	11	90.80
		Market cream.....	9	91.40
City milk contest, Cleveland, Ohio.....	Mar. 16, 1907.	Market milk.....	53	90.30
		Market cream.....	6	88.50
Granite State Dairymen's Association, Whitefield, N. H.....	Dec. 5-6, 1907.	Market milk.....	4	83.20
		Market cream.....	6	89.40
State Dairymen's Association, Marengo, Ill.....	Jan. 13-15, 1908.	Market milk.....	6	93.20
		Market cream.....	2	93.50
Pennsylvania State Dairy Union, Wilkes-Barre, Pa.....	Jan. 14-16, 1908.	Market milk.....	10	91.90
		Certified milk.....	4	95.80
State Dairymen's Association, Columbus, Ohio.....	Feb. 12-14, 1908.	Market milk.....	10	89.90
		Market cream.....	12	90.00
State Dairymen's Association, Battle Creek, Mich.....	Feb. 19-21, 1908.	Market milk.....	5	95.50
		Market cream.....	4	94.40
City milk contest, Cleveland, Ohio.....	Mar. 7, 1908.	Market milk.....	38	88.50
		Market cream.....	6	90.50
State Dairymen's Association, Traverse City, Mich.....	Mar. 11, 1908.	Market milk.....	10	91.10
City milk contest, Pittsburgh, Pa.....	Oct. 22, 1908.	Market milk.....	50	85.20
		Market cream.....	8	77.70
		Market milk.....	30	85.70
National Dairy Show, Chicago, Ill.....	Dec. 2-10, 1908.	Market cream.....	20	83.80
		Certified milk.....	14	90.20
		Certified cream.....	6	85.90
State Dairymen's Association, Dexter, Me.....	Dec. 8-10, 1908.	Market milk.....	39	91.60
		Market cream.....	31	88.60
State Dairymen's Association, Burlington, Vt.....	Jan. 6, 1909.	Market milk.....	29	90.60
		Market cream.....	16	81.30
Granite State Dairymen's Association, Contoocook, N. H.....	Jan. 13-14, 1909.	Market milk.....	5	92.50
		Market cream.....	7	90.40
City milk contest, Columbus, Ohio.....	Feb. 5, 1909.	Market milk.....	15	91.80
		Market cream.....	7	92.30
State Dairymen's Association, Grand Rapids, Mich.....	Feb. 17-19, 1909.	Market milk.....	6	81.10
		Market cream.....	4	95.20
City milk contest, Toledo, Ohio.....	Feb. 27, 1909.	Market milk.....	7	90.80
		Market cream.....	5	86.00
Kentucky Dairy Cattle Club, Lexington, Ky.....	Mar. 13, 1909.	Market milk.....	4	94.20
Michigan Dairymen's and Grand Traverse Dairymen's Associations, Traverse City, Mich.....	Mar. 25, 1909.	Market milk.....	6	93.50
City milk show, Cincinnati, Ohio.....	May 7, 1909.	Market milk.....	47	83.80
		Certified milk.....	25	87.71
		Market milk.....	39	90.63
City milk show, Grand Rapids, Mich.....	May 14, 1909.	Market cream.....	14	89.59
		Market milk.....	11	90.71
City milk show, Dayton, Ohio.....	Sept. —, 1909.	Market cream.....	1	91.00
		Market milk.....	7	74.70
Illinois State Fair, Springfield, Ill.....	Oct. 1-9, 1909.	Market cream.....	7	78.80
		Certified milk.....	2	72.00
		Market milk.....	21	85.05
National Dairy Show, Milwaukee, Wis.....	do.....	Market cream.....	13	85.12
		Certified milk.....	12	79.10
		Certified cream.....	6	81.75
City milk show, Pittsburgh, Pa.....	Nov. 4, 1909.	Market milk.....	44	89.24
		Market cream.....	4	92.10
Maine Dairymen's Association, Skowhegan, Me.....	Dec. 1, 1909.	Market milk.....	51	89.70
		Market cream.....	31	86.00
Michigan Dairymen's Association, Detroit, Mich.....	Feb. 4, 1910.	Market milk.....	8	95.81

Summary to February 4, 1910.

Number of contests.....			28
Samples entered... 893	Milk..... 654	Certified.....	65
		Market.....	589
	Cream..... 239	Certified.....	12
		Market.....	227
Average scores.....	Certified milk.....		87.54
	Certified cream.....		83.83
	Market milk.....		88.77
	Market cream.....		87.47

It should be stated that up to this date certified milk and market milk were judged by different standards; hence it is owing to this fact and not to inferiority that the former has a lower average score than the market milk. During 1910 new score cards for milk and cream were devised, which gave greater weight to the bacterial count and less to flavor and chemical composition. The results of the competitions during the use of the second form of score card are as follows:

List of milk and cream contests held in cooperation with the Dairy Division during the use of second score card.

Name and place.	Date.	Product.	Number of entries.	Average score.
Illinois State Fair, Springfield, Ill.....	Oct. 4, 1910....	Certified milk.....	1	90.30
		Certified cream.....	1	95.00
		Market milk.....	13	68.77
		Market cream.....	6	67.22
National Dairy Show, Chicago, Ill.....	{ Oct. 19 - 29, 1910.	Certified milk.....	30	86.75
		Certified cream.....	8	85.45
		Market milk.....	51	85.13
		Market cream.....	16	79.11
State Dairymen's Association, Baltimore, Md.	Nov., 1910....	Market milk.....	37	75.91
		Certified milk.....	3	91.50
		Certified cream.....	3	87.33
		Market milk.....	7	75.93
Kentucky Dairy Cattle Club, Lexington, Ky..	Jan. 3-5, 1911..	Market cream.....	3	69.33
		Market milk.....	13	89.98
		Market cream.....	3	83.66
		Certified milk.....	1	86.75
State Dairymen's Association, Roanoke, Va..	{ Jan. 23 - 27, 1911.	Market milk.....	8	87.55
		Market cream.....	2	75.13
		Certified milk.....	16	86.18
		Certified cream.....	2	89.25
Philadelphia Milk Show, Philadelphia, Pa....	{ May 20 - 27, 1911.	Market milk.....	16	85.13
		Market cream.....	4	74.56
		Market milk.....	111	75.40
		Market cream.....	4	79.56
City milk show, Detroit, Mich.....	{ Sept. 25 - 26, 1911.	Certified milk.....	1	83.90
		Certified cream.....	1	86.25
		Market milk.....	16	77.46
		Market cream.....	14	80.26
State fair, Springfield, Ill.....	{ Sept. 29-Oct. 7, 1911.	Certified milk.....	17	88.46
		Certified cream.....	4	91.28
		Market milk.....	28	84.68
		Market cream.....	18	80.09
National Dairy Show, Chicago, Ill.	{ Oct. 26-Nov. 4, 1911.	Market cream.....	1	92.25
		Market milk.....	17	85.63
		Certified milk.....	1	93.25
		Certified cream.....	3	88.75
Muskegon Milk Show, Muskegon, Mich.....	Dec. 6-9, 1911..	Market milk.....	42	85.33
		Market cream.....	1	95.00
		Certified milk.....	40	92.06
		Market cream.....	14	87.21
State dairy union, Pittsburgh, Pa.....	{ Jan. 15 - 20, 1912.	Market milk.....	3	94.65
		Market cream.....		
Farmers' week show, Amherst, Mass.....	Mar., 1912....	Market milk.....		
City show, South Bend, Ind.....	June 12, 1912..	Market milk.....		
		Market cream.....		

List of milk and cream contests held in cooperation with the Dairy Division during the use of second score card—Continued.

Name and place.	Date.	Product.	Number of entries.	Average score.
National Dairy Show, Chicago, Ill.....	{Oct. 24-Nov. 2, 1912.	Certified milk.....	15	91.18
		Certified cream.....	2	89.65
		Market milk.....	39	85.14
		Market cream.....	18	79.75
City milk show, Detroit, Mich.....	{Nov. 11-12, 1912.	Market milk.....	163	81.57
		Market cream.....	7	91.62
Pacific International Dairy Show, Portland, Oreg.....	{Nov. 21, 1912.	Certified milk.....	7	91.95
		Market milk.....	5	91.73
		Market cream.....	1	95.40
City milk show, Jacksonville, Fla.....	Dec. 14-21, 1912.	Market milk.....	21	91.39
State Dairy Union, Harrisburg, Pa.....	Jan. 22, 1913...	Certified milk.....	3	93.79
		Market milk.....	30	88.43
		Market cream.....	4	89.86
State Dairymen's Association, Saginaw, Mich.....	Feb. 4-7, 1913.	Market milk.....	23	85.53
		Market cream.....	7	82.40
State Dairymen's Association, Richmond, Va.....	Feb. 6, 1913...	Market milk.....	16	80.09
		Market cream.....	4	88.19
Bureau of Social Service, Muskegon, Mich.....	Feb. 7-10, 1913	Market milk.....	17	92.07
		Market cream.....	1	92.65
Farmers' week show, Amherst, Mass.....	Mar. 19, 1913...	Certified milk.....	2	92.60
		Market milk.....	63	88.93
		Market cream.....	16	88.42
Industrial Exposition, Rochester, N. Y.....	Sept. 16, 1913...	Market milk.....	15	85.67
		Certified milk.....	2	95.13
State Fair, North Yakima, Wash.....	Oct. 1, 1913....	Market milk.....	27	75.11
		Pasteurized milk.....	6	57.11
City milk show, Tacoma, Wash.....	Oct., 1913.....	Market milk.....	28	63.13
		Pasteurized milk.....	2	63.22
National Dairy Show, Chicago, Ill.....	{Oct. 23-Nov. 1, 1913.	Certified milk.....	23	90.58
		Market milk.....	73	92.22
		Market cream.....	19	88.68
State milk show, Springfield, Mass.....	Dec. 2-3, 1913..	Market milk.....	145	88.06
		Market cream.....	24	80.94
State Dairy Union, York, Pa.....	Jan. 13, 1914...	Certified milk.....	4	90.20
		Market milk.....	19	88.28
City milk show, Salt Lake City, Utah.....	Jan. 22, 1914...	Market milk.....	39	67.72
		Pasteurized milk.....	6	56.21
State Dairymen's Association, Grand Rapids, Mich.....	Feb. 10-13, 1914.	Market milk.....	39	87.58
		Market cream.....	9	79.37
Farmers' week, Amherst, Mass.....	Mar. 18, 1914...	Market milk.....	95	89.29
		Market cream.....	23	87.09
City show, Tacoma, Wash.....	Apr. 21, 1914...	Market milk.....	42	72.36
American Association of Medical Milk Commissions, Rochester, N. Y.....	June 10, 1914...	Certified milk.....	17	86.63
		Market milk.....	17	86.95
Charter Oak Fair, Hartford, Conn.....	Aug. 27, 1914...	Market milk.....	18	85.50
		Market cream.....	10	76.45
State Fair, Detroit, Mich.....	{Sept. 7-18, 1914.	Certified milk.....	2	80.32
		Market milk.....	111	81.49
		Market cream.....	4	81.85
National Dairy Show, Chicago, Ill.....	Oct. 24, 1914...	Certified milk.....	19	91.31
		Market milk.....	64	89.61
		Market cream.....	18	88.97
Chamber of Commerce, Cumberland, Md.....	Nov. 9, 1914...	Market milk.....	17	84.89
State show, Worcester, Mass.....	Dec. 2, 1914...	Market milk.....	133	89.37
		Market cream.....	24	87.91
State Dairymen's Association, Manchester, N. H.....	{Feb. 10, 1915..	Market milk.....	45	92.28
		Market cream.....	8	92.10
Pure-food department show, Tampa, Fla.....	Feb. 12-16, 1915.	Market milk.....	23	84.77
State Dairymen's Association, Flint, Mich.....	Feb. 17, 1915..	Market milk.....	39	89.88
		Market cream.....	5	90.40
City milkshow, Grand Rapids, Mich.....	Feb. 22, 1915..	Market milk.....	26	83.82
		Market cream.....	13	73.77
City milkshow, Pontiac, Mich.....	Feb. 25, 1915..	Market milk.....	36	89.79
		Market cream.....	75	88.52
Farmers' week show, Amherst, Mass.....	Mar. 19, 1915..	Market cream.....	20	91.72
		Pasteurized milk.....	6	87.25

Summary of scores made with the second card.

Number of contests.....				45
Number of samples.....	2,434	{Milk..... 2,090	{Certified..... 165	
			{Market..... 1,905	
			{Pasteurized..... 20	
		{Cream..... 344	{Certified..... 21	
			{Market..... 323	

The following-named contests, on account of the different methods of collecting samples, are not included in the averages:

Name and place.	Date.	Product.	Number of entries.	Averages.
State Dairymen's Association, Baltimore, Md...	Dec. 7-8, 1911	Market milk.....	33	67.07
	Nov. 20, 1912	Market milk.....	17	81.18
	Nov. 15, 1913	Market milk.....	47	71.05
Granite State Dairymen's Association, Concord, N. H.....	Feb. 11-12, 1914	Market milk.....	26	(¹)
		Market cream.....	4	(¹)
		Certified milk.....	2	93.33
City show, Portland, Oreg.....	Mar. 20, 1914	Market milk.....	106	76.19
		Pasteurized milk.....	17	69.44
		Certified milk.....	5	95.37
City show, Seattle, Wash.....	May 18, 1914	Market milk.....	76	82.63
		Pasteurized milk.....	17	66.21
		Certified milk.....	2	93.12
City show, Portland, Oreg.....	June 8, 1914	Market milk.....	105	85.88
		Pasteurized milk.....	10	84.19
		Certified milk.....	5	94.21
City show, Seattle, Wash.....	Sept. 9, 1914	Market milk.....	73	76.56
		Pasteurized milk.....	15	67.28
		Certified milk.....	35	(¹)
Illinois State Fair, Springfield, Ill.....	Sept. 18, 1914	Market milk.....	25	82.01
State Dairymen's Association, Baltimore, Md...	Nov. 13, 1914	Market milk.....	2	94.70
City show, Portland, Oreg.....	Dec. 11, 1914	Market milk.....	111	87.66
		Pasteurized milk.....	15	88.36
		Certified milk.....	5	95.34
City show, Seattle, Wash.....	Jan. 8, 1915	Market milk.....	80	83.06
		Pasteurized milk.....	19	72.18
		Certified milk.....	2	95.12
City show, Portland, Oreg.....	Mar. 31, 1915	Market milk.....	101	90.42
		Pasteurized milk.....	15	88.60
Portland Pure Milk Co., Portland, Oreg.....	Jan. 29, 1915	Market milk.....	63	91.59

¹ No data.

One hundred and twenty-nine other samples have been judged under regulations somewhat different from those described.

AVERAGE SCORES OF RECENT CONTESTS.

The average scores of the contests in which the second score cards were used are as follows:

Average scores, in detail, of contests where the second cards were used.

Item.	Milk.			Cream.		
	Perfect score.	Certified.	Market.	Perfect score.	Certified.	Market.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Bacteria.....	35	31.04	30.51	35	28.83	26.00
Flavor and odor.....	25	20.29	22.95	25	20.43	20.08
Visible dirt.....	10	8.85	8.67	10	9.28	9.18
Fat.....	10	9.33	9.19	20	19.52	19.91
Solids not fat.....	10	9.53	9.09	.....	.....	.....
Acidity.....	5	4.94	4.89	5	4.76	4.85
Bottle and cap.....	5	4.94	4.62	5	4.77	4.73
Total.....	100	88.92	89.92	100	87.59	84.75

To demonstrate further the weakest points in the samples entered in these contests, the table below shows the scores on each class of milk and cream in terms which indicate the per cent of the average score to the perfect score.

Per cent of perfection attained by samples in preceding table.

Item.	Milk.		Cream.	
	Certi- fied.	Market.	Certi- fied.	Market.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Bacteria.....	88.68	87.17	82.37	74.28
Flavor and odor.....	81.16	91.80	81.72	80.32
Visible dirt.....	88.50	86.70	92.80	91.80
Fat.....	93.30	91.90	97.60	99.55
Solids not fat.....	95.30	91.90		
Acidity.....	98.80	97.80	95.20	97.00
Bottle and cap.....	98.80	92.40	95.40	94.60

These two tables bring out some very interesting data concerning the samples of milk and cream entered.

It is believed that the second form of the milk and cream score card which was in use gave a great deal better analysis of the quality of the milk than the old one. The first milk and cream score cards put certified milk and cream at a disadvantage, as different cards were used for the certified and market classes, the standards for certified milk being much higher. This must be remembered in examining the average scores made in the contests held while the first cards were in use. Also a higher standard was made for acidity in certified milk than in market milk.

It was decided after much deliberation that only one score card should be used for milk, whether it be certified or market. The great point to be made in the consideration of milk is its value as a food for infants, so in the final analysis all milk must be considered from the same standpoint when held up to the standard of perfection.

The second card balanced up the desirable characteristics in a much better way than the old, and the results seem to justify the change. Certified milk averaged better than market milk on every point except on flavor and odor, where it fell about $2\frac{1}{2}$ points behind market milk.

The average score of the certified milk for bacteria, 31.04 per cent, indicates that the average sample submitted contained from 6,000 to 7,000 bacteria per cubic centimeter. The average fat content was between 3.6 and 3.7 per cent. The average solids not fat were almost 8.7 per cent, while the average acidity ran between 0.2 and 0.21 per cent. In the market milk the average score indicates a bacterial count of between 7,000 and 8,000; the fats average between 3.5 and 3.6 per cent; the solids not fat between 8.6 and 8.7 per cent; while the acidity was between 0.2 and 0.21 per cent.

Considering that some of the samples above were shipped 2,000 miles or more, were several days in transit, and after their arrival they were held in storage for several days, making them over a week

old when scored, the showing is remarkable and points out very strongly the fact that milk properly produced and handled and thoroughly refrigerated in transit and storage can be kept sweet for a considerable length of time.

The latest card shown on page 7 is more nearly uniform as to cuts in bacterial rating than the former cards. For the same increase in bacteria practically the same cuts are made, there being no serious breaks.

BENEFITS OF MILK CONTESTS TO DAIRYMEN.

As milk and cream contests are intended primarily for the education of the dairymen, it is interesting to go over the scores made in some of these contests to see whether they accomplish the purpose. In examining the scores of contests which have been held in the same place two years in succession, two things are very noticeable. The first is that dairymen who compete for two successive years almost always do better in a second contest than they did in their first, showing very plainly that they have received valuable suggestions as to the production of sanitary milk. The second is that dairymen who have had experience in these competitions nearly always do better than those who are competing for the first time. The following results which have been tabulated from three contests show conclusive figures along these lines:

MARYLAND STATE DAIRYMEN'S ASSOCIATION, 1911 CONTEST.

	Average score.
10 men who competed the year previous.....	73.83
23 men competing for the first time.....	64.15

ILLINOIS STATE FAIR.

	Average score 1910.	Average score 1911.
7 dairies which competed both years.....	74.64	79.68
7 dairies which did not compete in 1910.....		64.39

NATIONAL DAIRY SHOW.

Market milk:		
5 dairies which competed both years.....	89.50	89.53
23 dairies which did not compete in 1910.....		83.62
Certified milk:		
14 dairies which competed both years.....	83.10	91.05
3 dairies which did not compete in 1910.....		75.72

Looking at the Maryland State Dairymen's Association's 1911 contest, it is seen that the 10 men who had had previous experience in preparing milk for contests averaged more than 9 points better on the score card than those men who were competing for the first time.

At the Illinois State Fair in 1911 those who had competed the previous year bettered their former scores by more than 5 points and

averaged more than 15 points higher than the dairymen who were competing for the first time.

The scores made by both market and certified milk samples at the National Dairy Shows in 1910 and 1911 have been compiled, and they show similar results for the two years, though in the case of market milk the improvement from 1910 to 1911 is very small; but the fact that the dairies which had had the advantage of a previous competition averaged 6 points better than the new competitors bears out the truth of the statements made in this connection. The improvement in the certified milk was very remarkable, as in 1911 14 dairies increased their 1910 score by nearly 8 points and exceeded by more than 15 points the 3 certified dairies which were competing for the first time.

These figures, which are the result of the compilation of a large number of samples, show how the dairyman is taught by these contests to improve the quality of his products. The score cards made on each exhibit of milk and cream are always sent to the competitors with comments on the defects of the product, and they should contain suggestions for improvement. Progressive dairymen everywhere are availing themselves of the benefits derived from these contests and are finding that the competition aids them in many ways.

EXTRACTS FROM LETTERS.

The following are quotations from letters that have been received from dairymen subsequent to milk contests:

I was so much surprised on the following morning after the announcement; when I arrived in town the people came in every direction to congratulate me on my success; I could not believe it. From the fact that there are so many older and more experienced dairymen than myself I was not expecting anything of the kind.

I have this much confidence in myself that if I won this time I will try again. I have discovered where I can make much improvement next time in flavor.

I expect to use narrow-top pails hereafter. I use straw for bedding; I dampen my bedding with a sprinkler just before the cows go in. I washed my cow 12 hours before milking; later, I rubbed her down one hour before milking I rubbed her down again with a damp cloth.

* * * * * * *

We are very glad that we had our goods entered. The winning of cup and honorable mention are a source of satisfaction, not from their value, but to know our standing.

We have been trying to produce good, clean, wholesome products, but did not know where we stood as compared with others, as this was our first entry.

It has certainly been a good advertisement for us, as we have not been able to fill our orders since.

* * * * * * *

Although my milk was not good enough to receive a diploma, I learned more than if it had scored better. The appearance of the samples on Friday made me think I was free of many undesirable kinds of bacteria, and I believe that if my methods are improved I can produce as good milk as is produced in the much more expensive plants.

SUGGESTIONS FOR THE PRODUCTION OF CONTEST MILK.

It has been found in examining the answers to the questions concerning the production and handling of the best samples of milk and cream entered in contests that the producers have in every case exercised great care, and that the results obtained bear out the principles which from time to time have been laid down as necessary for the production of pure milk. It is not the purpose here to go into great detail regarding all methods which might be used, but a short résumé of the more important things to be considered in preparing a sample of milk or cream to enter in one of these contests will be presented.

BACTERIA.

As the bacterial count has so much weight on the score card, it will very naturally be the source of much consideration on the part of the producer. The bacterial count in samples entered in past contests has varied from below 100 to several millions per cubic centimeter. As it can be assumed that any one preparing samples for contests will exercise all the care and intelligence which he possesses, it must be concluded that at the present time many of our producers do not understand just where the bacteria come from and how their entrance into the milk can be prevented.

First of all, in the production of milk which will have a low bacterial count, it is necessary to have absolute cleanliness in every branch of the work. The barn itself and the barn air must be free from dust at the time of milking. This can be accomplished by keeping the walls, ceiling, and floors scrupulously clean, and some producers just before milking time have even gone so far as to sprinkle the air in the barn, and also the bedding, with a fine spray of water to lay the dust. The cow herself is a source of very dangerous bacterial contamination. She very often carries on her skin dust, dry manure, loose hair, and other impurities, which fall into the milk pail during the process of milking. To produce milk of the highest grade it is necessary to have the cows thoroughly groomed with the currycomb and brush. Just before milking is commenced the cow's udder and flanks should either be wiped with a damp rag or the parts thoroughly washed and then dried with a clean towel, so that no water can drip from the body into the milk pail. Better results are obtained, however, if the cow's hair is slightly moist during milking. This method washes from the cow's hide much dust and dirt which might not be removed by currying. The hands of the milker should be thoroughly cleaned, and to secure the best results he should milk dry-handed.

It has been demonstrated that a large number of the bacteria that get into the milk may be excluded by the use of a small-top pail, which protects the milk from dust and germs which may drop from

the cow's body. All utensils, such as pails, strainers, bottles, dippers, etc., which come into contact with the milk, should be sterilized with either live steam or boiling water. Many dairymen make the mistake of thoroughly washing the bottles and then rinsing them with water which is only warm. This does not kill the bacteria which may be on the surface of the utensils, and considerable contamination ensues. Many competitors have been in the habit of discarding the first few streams of milk that come from each teat, for it is known that the first milk drawn contains a larger proportion of bacteria than that which follows. Milking should be done as quickly as possible and with as little agitation of the cow's udder as is possible, as such a disturbance is very liable to shake bacteria from the cow's hide into the milk pail.

As milk is so easily contaminated it is necessary, as soon as drawn, to take it to a clean, convenient milk house, where it can be cooled immediately. The milk house should be well protected against flies and should be scrupulously clean. As bacteria grow very fast in warm milk, prompt cooling is an absolute necessity. Fresh milk containing 100 bacteria per cubic centimeter, if not cooled will in the course of time contain the offspring of the original bacteria which may amount to millions. In the scoring of cream it has been noticed that the bacterial count has averaged higher than that of the milk samples submitted. This may be attributable to the fact that clumps of bacteria are broken up by the force of the separator, and hence an apparently larger count is the result, or it may be caused by milk passing through one more piece of apparatus, namely, the separator, which is not always thoroughly cleaned and sterilized.

The bottles into which the product is put and the caps with which they are sealed should be sterilized so that no contamination can ensue. In cooling the milk it is not necessary that any special form of cooler be used. In fact, many of the successful competitors in the past who have obtained very low bacterial counts have believed that the exposure of the milk to the air in passing over a cooler was not a desirable feature, and have bottled the milk warm and cooled it with ice water. While this method does not cool the milk quite so quickly, it saves it from any possible contamination caused by exposing it in a thin sheet to the air. Bottles should be kept in ice or ice water until ready for shipment; then they should be packed in a durable shipping case surrounded with ice and forwarded without delay.

FLAVOR AND ODOR.

Several causes contribute to undesirable flavors and odors in milk and cream. One instance is the flavor which is the result of bacterial action. This may be owing to the lactic-acid bacteria which sours

milk. In some contests those in charge have received samples that were actually curdled; such milk, being of no value as market milk, could not, of course, get credit for flavor or odor. Then certain forms of bacteria cause fermentation or decomposition in milk, and when they have worked for a considerable length of time they cause a very undesirable flavor.

Certain feeds also contribute to the flavor and odor. In several competitions milk scores have been cut heavily because of a pronounced garlic flavor. Silage flavor is very often in evidence, especially during cold spells in the winter when the barns are kept tightly closed. If the silage is fed directly after milking instead of either before or during milking, there should be no trouble on account of silage flavor in milk. There is one thing, however, that must be remembered: If the cows leave any silage in the mangers it must be cleaned out and taken from the barn when they are through, as the warm milk very readily absorbs the silage odor if it is in the air. The stable air, if close or "cowy," is another source of bad odors which are absorbed by the milk. Sometimes flavors are detected in milk which are due to foreign substances. Milk has been submitted in bottles from the rubber parts of which it had absorbed a flavor of rubber. The use of unparaffined caps may give rise to a "brown paper" flavor in the milk.

It would seem that the best results, so far as flavor and odor go, can be secured by mixing the milk of three or more cows. Sometimes the physical condition of the cow or the period of her lactation influences the flavor of the milk considerably, so that if the milk from only one cow is submitted there is a risk of the individuality of the cow playing some part in the flavor. It is also best to avoid "stripper" milk on account of a strong flavor which very often develops.

VISIBLE DIRT.

With proper care in milking or even with proper care in straining there is no excuse for large amounts of sediment in milk. As a matter of fact, however, few samples, even in the certified milk class, have been scored perfect on this point, and some samples have been so extremely dirty as to receive a zero on the score card. The sediment usually found is a fine, dark-brown or black precipitate, which is the result of dust and dried manure finding its way from the cow's hide into the milk. Some of this fine sediment in a state of temporary suspension in the milk may pass through coarse strainer cloths, if such are used, and settle to the bottom of the bottle after the milk is allowed to stand for any considerable time. Very often large pieces of foreign matter have found their way into the milk. In some cases it is almost unbelievable that such matter could get into contest

milk and escape the observation of the producer. Bits of straw or hay an inch or an inch and a half long have been found in the bottom of the bottle, and cow hairs are often found in the sediment, and occasionally bristles from brushes.

To avoid visible dirt in the milk and thus receive a high score on this point it is necessary to follow the rules for cleanliness laid down under the heading "Bacteria." Sometimes the sediment is due to the fact that pails or bottles after being sterilized are allowed to stand uncovered. If there is any wind stirring, chaff, dust, etc., are almost sure to be blown into the pails or bottles and will thus appear as sediment in the milk. Coarse strainers should be avoided if the producer wishes to get all the fine dirt out of the milk. The best results in the past have probably been secured with the use of cotton as a straining medium. Various forms of cotton are on the market, some in bulk and some prepared in thin sheets especially for straining. In the answers to questions on the production of milk for contests there does not seem to be any special advantage in milking on to a strainer over the milk pail. Unless the strainer cloth is changed when each cow is milked such a practice is liable to result in worse contamination than when the milk is simply milked into an open pail and then strained into the can.

FAT AND SOLIDS NOT FAT.

Except in occasional cases a normal milk having a fat content of 4 per cent contains more than 8.7 per cent of solids not fat. In some contests several samples have been entered which apparently had been modified by the producer in the attempt to obtain a higher score on chemical composition. Milks testing 8 per cent of fat and over have been submitted. Fortunately, such an adulteration is very easily seen by the judges when the fat is compared with the solids not fat. The contestant who tries to improve upon nature in this manner often decreases, rather than increases, his score. Any milk containing as much as 4 per cent of fat receives a perfect score, so that an 8 per cent milk gets no higher score on fat than a 4 per cent milk. The result of adding cream to milk to bring it from a 4 per cent to an 8 per cent fat is to lower the proportion of solids not fat in the milk, so that the score on that item is sometimes cut considerably. In normal milk the solids not fat increase as the fat increases but not in the same ratio. In milk to which cream has been added, however, the fat increases and the solids not fat are decreased.

To eliminate contact with all unnecessary utensils some contestants have milked directly into the milk bottle. The first part of the milk drawn from the cow is quite deficient in fat, while the very last of the milk runs high in that constituent. In order to have a normal

chemical composition in milk it is necessary to mix the entire milk from one or more cows.

ACIDITY.

The presence of acid-forming bacteria in milk in large numbers is usually responsible for a high acidity. It may be that there are other factors which play an important part in the acidity of milk, but at the present time they are not well understood. To keep down the acidity of milk caused by acid-forming bacteria it is necessary to keep the bacterial count as low as possible by following the precautionary measures previously mentioned. To check the growth of bacteria the milk should be thoroughly iced from the time of milking until it is scored.

BOTTLE AND CAP.

It is best to select bottles which are made of clear glass and which are free from flaws and other imperfections. The bottles should be filled up to the cap seat with the milk or cream. The cap should fit the mouth of the bottle tight enough to prevent leakage but not so tight that it will have to be jammed in order to force it into place. When it is in place melted paraffin may be poured on it, taking care to fill the depression in which the cap rests. The bottle top may be protected by waterproof material, such as oiled or paraffined paper, tin or tin-foil caps, etc. The most common cut against the appearance of the bottle and cap has been made because either the bottles have not been filled or because the cap and the mouth of the bottle were not properly protected. The protection of the mouth of the bottle is important not only from the standpoint of appearance but because iced cases of bottles are piled one above the other and often the dirty water resulting from the mixture of dust and melted ice trickles down upon the bottles.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATING TO MILK AND CREAM.

AVAILABLE FOR FREE DISTRIBUTION.

- The Application of Refrigeration to the Handling of Milk. (Department Bulletin 98.)
The Alcohol Test in Relation to Milk. (Department Bulletin 202.)
Estimation of Total Solids in Milk by Use of Formulas. (Bureau of Animal Industry Bulletin 134.)
Influence of Stage of Lactation on Composition and Properties of Milk. (Bureau of Animal Industry Bulletin 155.)
Chemical Changes Produced in Cows' Milk by Pasteurization. (Bureau of Animal Industry Bulletin 166.)
Extra Cost of Producing Clean Milk. (Bureau of Animal Industry Circular 170.)
Utilization of Exhaust Steam for Heating Boiler Feed Water and Wash Water in Milk Plants, Creameries, and Dairies. (Bureau of Animal Industry Circular 209.)
Use of Milk as Food. (Farmers Bulletin 363.)
Care of Milk and Its Use in Home. (Farmers Bulletin 413.)
Bacteria in Milk. (Farmers Bulletin 490.)
Grading of Cream. (Separate 536 from Yearbook 1910.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS

- Medical Milk Commissions and Certified Milk. (Department Bulletin 1.) Price, 10 cents.
Fat Testing of Cream by Babcock Method. (Bureau of Animal Industry Bulletin 58.) Price, 5 cents.
Bacteria of Pasteurized and Unpasteurized Milk Under Laboratory Conditions. (Bureau of Animal Industry Bulletin 73.) Price, 5 cents.
Market Milk Investigations: 2. Milk and Cream Exhibit at National Dairy Show. (Bureau of Animal Industry Bulletin 87.) Price, 10 cents.
Milking Machine as Factor in Dairying. Preliminary Report: 1. Practical Studies of Milking Machines; 2. Bacteriological Studies of Milking Machine. (Bureau of Animal Industry Bulletin 92.) Price, 15 cents.
Chemical and Physical Study of Large and Small Fat Globules in Cows' Milk. (Bureau of Animal Industry Bulletin 111.) Price, 5 cents.
Variations in Composition and Properties of Milk from Individual Cow. (Bureau of Animal Industry Bulletin 157.) Price, 5 cents.
Study of Bacteria Which Survive Pasteurization. (Bureau of Animal Industry Bulletin 161.) Price, 10 cents.
City Milk and Cream Contest as Practical Method of Improving Milk Supply. (Bureau of Animal Industry Circular 117.) Price, 5 cents.
Some Important Factors in Production of Sanitary Milk. (Bureau of Animal Industry Circular 142.) Price, 5 cents.
Competitive Exhibitions of Milk and Cream, with Report of Exhibition Held at Pittsburgh, Pa. (Bureau of Animal Industry Circular 151.) Price, 5 cents.
Improved Methods for Production of Market Milk by Ordinary Dairies. (Bureau of Animal Industry Circular 158.) Price, 5 cents.
Extra Cost of Producing Clean Milk. (Bureau of Animal Industry Circular 170.) Price, 5 cents.
Fermented Milks. (Bureau of Animal Industry Circular 171.) Price 5 cents.
Pasteurization of Milk. (Bureau of Animal Industry Circular 184.) Price, 5 cents.
Directions for Home Pasteurization of Milk. (Bureau of Animal Industry Circular 197.) Price, 5 cents.
Milk and Cream Contests and how to Control Them, and How to Prepare Samples for Competition. (Bureau of Animal Industry Circular 205.) Price, 5 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 357

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WM. A. TAYLOR, Chief



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ALASKA AND STONER, OR "MIRACLE," WHEATS: TWO VARIETIES MUCH MISREPRESENTED.

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INTRODUCTION.

There are many named varieties of wheat and other cereal crops. New varieties and new names for old varieties are appearing constantly. Many of these new varieties, or so-called varieties, are good; some are not. The good varieties are sometimes advertised as being much better than they really are. Varieties of little value sometimes are claimed to be the best of all.

There are various ways by which the promoters of supposed new varieties interest their customers. Sometimes it is a story of wheat of mysterious or foreign origin; sometimes it is a new or unusually developed character that is claimed. Examples of this are the enormous tillering power claimed for the so-called Miracle wheat or the

wonderful productiveness claimed for the branched heads of the so-called Alaska wheat. Always, however, the yields are said to be enormous. Sometimes the same variety is exploited again and again under a new name and with a new and wonderful story.¹

The present paper deals with two misrepresented varieties of wheat. They have had very interesting and varied histories in past years. This bulletin tells what they really are, gives the story of their origin, quotes the claims made for them, and states what they may reasonably be expected to do under average conditions.

Active efforts to promote the sale of these wheats are still being made and many farmers are being misled into purchasing them because of the plausible statements made by the promoters. The United States Department of Agriculture and the State agricultural experiment stations endeavor to keep informed concerning all such exploitations and to warn their constituents of the danger. The present paper is the result of this endeavor.

ALASKA WHEAT.

The so-called Alaska wheat is merely a very old variety under a new name. Attempts to promote it under one or another of its many names have been numerous and persistent for more than a hundred years. There is evidence that these exploitations usually have been profitable to promoters and expensive to purchasers. In order that the reader may know definitely some of the ways in which it has been promoted its history is given rather fully. Quotations from early American writers show former exploitations, while the most recent one is fully discussed. These instances should serve to put readers on guard against future exploitations. This wheat has never been proved to have value anywhere in the United States.

DESCRIPTION OF ALASKA WHEAT.

The variety recently exploited under the name Alaska wheat belongs to the poulard subspecies of wheat. Botanically, the poulard wheats are known as *Triticum turgidum* or *Triticum aestivum turgidum*. They are somewhat intermediate between the common and the durum wheats. All of them are bearded, and the beards are more or less intermediate in their length and color between those of common wheat and those of durum wheat. They have the peculiarly flattened heads, the broad chaff, and the amber kernels of the durums. The chaff, however, is rather thin and papery, and the kernels are shorter, softer, and more humpbacked than those of durum wheat.

These wheats are not grown commercially anywhere in this country, and the relationships of the different varieties are not well known.

¹ See Ball, C. R. "Three much-misrepresented sorghums," U. S. Dept. Agr., Bur. Plant Indus. Cir. 50, 14 p., 2 fig. 1910.

The chaff is usually without hairs, but sometimes it is hairy. Some have simple heads, like the common and durum wheats; others have branched heads.

The poulard variety here discussed as Alaska wheat is fairly well known in the United States. It has branched heads and no hairs on the chaff. It has been advertised many different times under many names, but has never become permanently established. On account



FIG. 1.—Large, medium, and small heads of Alaska wheat. (About half natural size.)

of the large, branching head it has always been easy to interest people in this variety. Heads of this wheat are shown in figure 1.

EARLY HISTORY OF ALASKA WHEAT.

Poulard wheat in one or another of its forms is grown to some extent in the Mediterranean region of Europe. This variety of poulard wheat with branched head has been known in this country under many different names. Among them are Alaska, Egyptian, Eldorado, Jerusalem, Many-Headed, Many-Spiked, Miracle, Multiple-Headed, Mummy, Reed, Seven-Headed, Smyrna, Syrian, Wheat

of Miracle, Wheat 3,000 Years Old, and Wild Goose. It is probable that as many more names for this variety could be found if early agricultural literature were searched.

Like many other crops, it probably was introduced in colonial days. In 1815, a letter dated 1807 and signed by John Keemle¹ was published concerning a so-called Jerusalem wheat. This was a part of a small crop produced by Dr. Keemle from seed secured by him from Ireland and sown in the fall of 1806. These statements are found in this letter (p. 137):

Its productiveness may be estimated by the number of heads on a single straw, on some there are 3-5-7 heads, as you will observe by those I send you. The straw is 6 feet high, and very stout, sufficiently so to bear its own weight uncommonly well. The grain is full and plump, differently shaped from our wheat, and somewhat larger.

From this it is evident that the Jerusalem wheat of 1807 was identical with the Alaska wheat of the present time.

In connection with this letter the origin of the name Jerusalem is given by Dr. J. Mease,² secretary of the Philadelphia society. According to this statement, a small sheaf of this wheat was brought from Palestine by a traveler and used as "a sign to an alehouse which he kept for some years after in Dublin." Some seeds from this sheaf were picked up and planted by a farmer, who several years later sold the produce of several acres at about \$3.65 a pound. Dr. Mease further states (p. 138):

It is believed that the same variety of wheat was introduced into this country in 1792, as some of a kind answering to the description of the Jerusalem wheat was presented to the society, and distributed among the members, but as it has been lost it is more than probable it possessed no particular good qualities.

In the issue of the *American Farmer* for September 26, 1840, there is an engraving from a drawing of a head of wheat, without doubt the same as the Alaska wheat of the present time. This wheat was grown by Mr. Alpheus Baker,³ of Abbeville, S. C., who is quoted in part as follows:

The wheat to which you allude was brought to this place from the Osage Nation, by Col. Spieren, who had been sent to them as a commissioner by the President of the United States. * * * We sell the wheat at \$5 per head.

In the same journal, in the issue of October 7, 1840, Mr. Gideon B. Smith,⁴ of Baltimore, Md., writes as follows:

¹ Keemle, John. On Jerusalem wheat. *In* Mem. Phila. Soc. Prom. Agr., v. 1, p. 135-137. 1815.

² Mease, James. On Jerusalem wheat. *In* Mem. Phila. Soc. Prom. Agr., v. 1, p. 137-138, 1815.

³ Baker, Alpheus. [A new wheat.] *In* Amer. Farmer, n. s., v. 2, no. 19, p. 148, 1 fig. 1840.

⁴ Smith, Gideon B. The new species of wheat. *In* Amer. Farmer, n. s., v. 2, no. 20, p. 154. 1840.

THE NEW SPECIES OF WHEAT.

BALTIMORE, October 3, 1840.

To the EDITOR OF THE AMERICAN FARMER.

SIR: I think it proper to take the earliest occasion to notice the new species of wheat, a drawing of which has just been published in the American Farmer and copied into the American and Patriot, accompanied by a letter from Mr. Read. I do this for the double purpose of saving money and trouble to all concerned. This new species of wheat is, without doubt, the Egyptian wheat *Triticum compositum*, for a drawing and description of which, see Loudon's Encyclopedia of Plants. The engraving in Loudon and that in the Farmer present the same characters precisely. Besides, I have often seen the Egyptian wheat, and the head of the new species which has been exhibited to me is identical with the Egyptian. This kind of wheat was introduced into England in 1799, and from that time to the present has made frequent appearances in the United States. It has been called successively the Egyptian, Syrian, Many-spiked, Seven-headed, Reed, Wild Goose wheat, etc. The name Wild Goose was given to it from the fact that a few grains of it were found some years ago in the crop of a wild goose that was killed on the shores of Lake Champlain. The name Reed wheat was given to it because of its stout stem resembling a small reed or cane. It was received by the Philadelphia Society for Promoting Agriculture, in 1807, from Gen. Armstrong, then our minister at Paris. Judge Peters took charge of a part of it, and grew it five or six years. It was at first very productive under his cultivation, a pint of seed sown in drills and hoed producing one bushel and a peck of grain. But after the first three or four years, the Judge says it did not thrive sufficient to authorize extensive cultivation. At that time it was extensively distributed by the above-named society. Judge Buel says he had seen extensive fields of it.

In the Domestic Encyclopedia, published in 1821, it is stated that the Egyptian wheat does not yield as much flour as any of the other kinds, and that the flour is scarcely superior to that obtained from the finest barley. In March, 1838, it was selling in Albany, N. Y., at \$5 per bushel. It has several times been brought from Santa Fe by travelers and traders. It appears to be cultivated in that country, probably owing to its better adaptation to the climate than other kinds. That the Osage Indians might have obtained it from Santa Fe is no way improbable. How it found its way from Egypt to Santa Fe I cannot pretend to guess, unless a wild goose also carried it from the former to the latter country, which, on reflection, is scarcely more improbable than the fact stated above, that one of these birds carried it to the shores of Lake Champlain.

From all these facts it would appear that if the wheat in question had been adapted to our climate, or was susceptible of acclimation, and in other respects a good variety, it would have gone into general cultivation long before this time, as I take it for granted that an article that had been so extensively distributed and so thoroughly experimented upon would have been retained and universally cultivated, if it had been found valuable. During the 20 years of my agricultural experience it has been presented to my notice at least 20 times.

Your obedient servant,

GIDEON B. SMITH.

The names Egyptian, Miracle, Mummy, and Wheat 3,000 Years Old all are derived from one of the most common untrue stories about this variety. The story varies somewhat in detail but in gen-

eral it tells that when the coffin of an Egyptian mummy 3,000 or 4,000 years old was opened, some wheat was found. Seed was planted, but only a single kernel grew. The resulting plant proved a wonderful yielder and very different from any wheat now known.

Of course, this story in all its forms is a fabrication, pure and simple. Stored under most favorable conditions, seeds of wheat will not keep their vitality more than a few years. No wheat thousands of years old has ever been known to germinate.

The name Egyptian wheat has recently been used in exploiting a very different crop, namely, a variety of sorghum properly known as shallu.¹ The name Miracle has been recently used for an entirely different kind of wheat. The name Wild Goose has been used also for Arnautka durum wheat and for Polish wheat.

It always has seemed easy to interest people in this wheat. The branched head and the mummy, wild-goose, and other stories have been the very profitable stock in trade of many a promoter. It seems very natural to many people that if an unbranched head will yield so much, a branched head should yield much more. Head for head, this may sometimes be true, but acre for acre it is not, as shown by the results of experiment. The wheat is not grown commercially anywhere in this country, and ought not to be until it is shown to possess better qualities than are known at present.

RECENT EXPLOITATION OF ALASKA WHEAT.

In the early summer of 1908 accounts of what was claimed to be a wonderful new wheat appeared in the press. These set forth in brief that in 1904 an Idaho farmer had found, in a secluded spot on the Alaskan coast, a wheat plant with branched heads. They further stated he had brought back one head and sowed its seed that fall, increasing the quantity to 7 pounds in 1905 and to 1,545 pounds in 1906, the latter being an increase of 220 fold, from which it was argued that sowing 1 bushel to the acre would produce 220 bushels.

One of the statements about the wheat which awakened much interest in the Eastern States was as follows:²

And, last and best of all, it will bring back wheat raising to the worn-out farms of the East, where, with wheat yields 200 bushels to the acre, farmers can afford to use manures and chemicals and make a profit.

There was obtained soon after a well-illustrated advertising circular containing exaggerated and misleading statements regarding the origin of the wheat, its yielding power, its milling value, its drought and cold resistance, its adaptability to poor soils, etc. This

¹ Ball, C. R. Three much-misrepresented sorghums. U. S. Dept. Agr., Bur. Plant Indus. Cir. 50, 14 p., 2 fig. 1910.

² Day, O. F. G. A miracle in wheat. *In* Sat. Even. Post, v. 181, no. 7, p. 11. 1908. The assertions made in this article were later disavowed by the paper. (Editorial, Sat. Even. Post, v. 181, no. 11, p. 16. 1908.)

bore the name of a seed-grain company in Juliaetta, Idaho, which offered a limited supply of the seed at \$20 per bushel.

The following quotations from this circular contain the claims made for the origin, character, yield, and value of the Alaska wheat:

THE BIRTH OF ALASKA.

Alaska wheat is the result of a bright idea on the part of Abraham Adams, an Idaho farmer, who realized the possibilities of a "double" wheat crop if it could be perfected. After working several years he perfected a head of wheat with one single central head, around which were nine other shorter heads. If this head would repeat in the planting, it meant a crop six to ten times greater than ordinary wheat.

The double head was planted in the fall of 1904, and the next summer 7 pounds resulted, and every head was double.

The 7 pounds planted in the spring of 1906 brought forth 1,545 pounds, 222½ times the plant made, or, at 1 bushel plant to the acre, 222½ bushels to the acre.

THE ALASKA WHEAT REVOLUTION.

It means that it is made possible to increase the wheat yield of the country tenfold when Alaska seed is plenty. It means that with Alaska wheat the farmer with a hundred acres finds his acreage value increased to a thousand acres.

Farmers in the winter-wheat countries will have a winter wheat that will be hard wheat instead of soft.

The worn-out farms of the East can again raise wheat, because with such a yield farmers can afford to use fertilizer and get valuable returns.

Farmers in dry countries will find in Alaska wheat an ideal wheat for dry land, where it flourishes, because its native spot was dry.

Farmers in hot countries will find a wheat that remains cool and green after two weeks of dry weather with the thermometer at 140° in the fields.

Farmers in cold countries will find a wheat that resists frost and hail that would ruin any other wheat.

ALASKA'S YIELD.

Regarding the trial of Alaska, a hundred bushels to the acre is only a small yield. It has run from 100 bushels to 222½ bushels to the acre in large tracts, and even more in favored places. Like all wheat, much will depend on the soil; the better the soil the larger the yield.

From correspondence with the promoter of the wheat, it is known that in the spring of 1908 samples of seed were sent to a chemist for analysis. The report of this analysis, submitted in May, 1908, was favorable to the wheat. Without making a milling test, the chemist reported that probably it would be as good as, if not superior to, Palouse Bluestem for flour-making purposes.

The United States Department of Agriculture early in June, 1908, began an investigation of the exploiting of this wheat. A warning statement, issued on August 18 following, was widely distributed. At the same time a cereal expert in the department was instructed to study the wheat in the Idaho fields and report on the yields obtained.

At Juliaetta, on September 4 and 5, 1908, the expert found about 700 acres of this wheat being grown for the seed company. The wheat in different fields was then being thrashed and was found to be yielding from 10 to 35 bushels per acre. The average was estimated to be about 25 bushels. Well-known wheat varieties of the Pacific Northwest were yielding as much and more under identical conditions. It was found that good farmers around Juliaetta were not growing this wheat.

This accords with a statement made by the promoting company in a later pamphlet to the effect that the farmers refused to rent their summer fallow for the growing of this wheat, and the promoters were obliged, therefore, to sow it on continuously cropped land.

Orders and remittances for the seed wheat were being received in large numbers. Most of the wheat was being shipped in bushel and half-bushel lots to farmers of the New England and Atlantic States. It will be remembered that the wheat had been advertised as having especial value for eastern conditions. An agent was spending his entire time taking orders in the South. Very little was found to have been sold in the Northwest. Many telegrams canceling orders were also being received, probably as a result of the press notice given out by the United States Department of Agriculture and of the disclaimer published by the paper which contained the original article.

A widespread controversy immediately arose concerning the identity and value of the so-called Alaska wheat. Those who had seed for sale claimed that it was a wheat of wonderful producing power. State and Federal investigators reported it to be nothing more or less than the old Egyptian or Seven-Headed wheat under a new name. Chemical analyses and milling and baking tests were made at several places, with results unfavorable to the flouring value of this wheat.

The Post Office Department in 1908 took account of the doubtful nature of the advertising matter being circulated and issued a fraud order against the promoting company.

In 1909, however, another campaign was begun in favor of the wheat. Various press items appeared contradicting the conclusions of the chemists and millers. It was claimed that the wheat was just as good for milling and baking purposes as the Palouse Blue-stem or any other wheat. A 12-page pamphlet was published by the promoting company, discussing the controversy which had arisen over the value of the wheat. Extracts from Idaho Agricultural Experiment Station Bulletin No. 65, issued in November, 1908, are included in this pamphlet.

Extracts from letters said to have been written by several well-known agronomists of the country are frankly included also, although unfavorable to the wheat. Their opinions may be summed up in these quotations:

Farmers are warned to avoid this wheat as they would a pestilence.

It is one of the poorest wheats known for flour-making purposes, and it is never grown where ordinary varieties of wheat will thrive.

Not even good for stock feed.

Shun it as you would the smallpox.

Warning against what I must now recognize as a brazen fraud.

The illustrations in this pamphlet are exactly the same as those in the original advertising circular. Some of the statements contained in the previous circular are repeated, and in addition affidavits from growers, thrashers, and others are included. The only figures in this circular from which a yield per acre can be determined are to the effect that on one field, in 1908, 501 sacks were thrashed from 30 acres. Assuming that these sacks contained the usual $2\frac{1}{4}$ bushels each, this yield would be only $37\frac{1}{2}$ bushels per acre. It is stated also that the 1,545 pounds grown in 1906 yielded 53,000 pounds in 1907. The acreage is not given, but this is an increase of only 35 fold. A greatly increased acreage was harvested in 1908, but the acre-yields are not given. In the pamphlet the price is still given as \$20 a bushel, for sale by a certain seed grain company.

Little more public attention was attracted to the Alaska wheat until the spring of 1915, when it was placed on exhibition by the promoter at the Panama-Pacific Exposition. Visitors at the exhibit were invited to take a copy of the pamphlet just discussed. It had been provided with a new cover, the last leaf of which is so pasted on as to cover the name of the seed grain company and the quoted price of \$20 a bushel. The front cover announces that Alaska wheat, "smut proof" and a "big yielder," is for sale by the promoter at Juliaetta, Idaho.

Early in 1915, also, still another exploitation of this wheat seemed to be getting under way. This time a Wyoming association offered the seed under the name of Egyptian Seven-Headed Wheat. The price was \$10 a bushel.

YIELDS OF ALASKA WHEAT.

An agent of the United States Department of Agriculture visited the field of Alaska wheat being grown in the vicinity of Juliaetta, Idaho, in 1908. There were about 700 acres in all. The yields were found to vary from 10 to about 35 bushels to the acre, the average yield being about 25 bushels. Other varieties, growing under conditions apparently identical, were yielding as much and more.

Regarding the yield of Alaska wheat, this statement is made by French and Jones.¹

The yields this season, 1908, have not been phenomenal in any way. In some cases the wheat was quite badly mixed with other varieties, such as Canadian Hybrid and Little Club. An estimate of the yield, verified in some cases by the thrashing-machine record, is from 20 to 40 bushels per acre. This is about the same yield as obtained from ordinary winter wheat this season. That it will exceed these yields when grown under field conditions remains to be proven.

Alaska wheat has been frequently tested in rows and small plats in several States in different sections of the country by the United States Department of Agriculture in cooperation with the respective State experiment stations. The results of some of these tests are here reported.

At Akron, Colo., when sown in 20-foot rows in the spring of 1909, two tests of Alaska wheat gave yields at the rate of 14 and 11 bushels per acre, respectively. There were 82 rows in the nursery of this year, exclusive of checkrows, consisting of many different varieties and strains. Of these, 69 yielded at rates in excess of 14 bushels per acre, the best of the Alaska yields.

In 1912 Alaska wheat was again tested at Akron in 20-foot rows and yielded 5.5 and 11.5 ounces per row, respectively, in two tests. There were in this year 114 rows in the nursery, exclusive of check rows, consisting of many varieties and strains. Of these, 28 yielded more than 11.5 ounces per row, the best yield of the Alaska wheat.

In 1913, at Akron, Alaska wheat was tested in nine rows, each about a rod in length. It varied in yield from 2 to 9 ounces per row, with an average of 5.8 ounces. There were no less than 60 rows of several varieties, out of more than 600 rows grown, that yielded more than 9 ounces, the best yield of the Alaska, and a great many more that yielded better than the average. In 1914, Alaska wheat again gave about an average yield in row tests at Akron.

When sown in short rows at Williston, N. Dak., in the spring of 1909, Alaska wheat was one of the poorest yielding varieties among the many durum and common kinds tested. It was so poor that it was not continued.

When sown in a 60-foot row at Belle Fourche, S. Dak., in the spring of 1912, Alaska wheat yielded about the amount of seed sown and was not continued.

When sown in rows a rod long at Cheyenne, Wyo., in the spring of 1913, Alaska wheat yielded a little more than the seed sown, or at the rate of about $1\frac{1}{3}$ bushels per acre. A common spring variety

¹ French, H. T., and Jones, J. S. Alaska wheat investigation. Idaho Agr. Exp. Sta. Bul. 65, p. 6. 1908.

yielded in a similar test about 7 bushels per acre. In 1914 at this place on a plat containing 1/142 of an acre it yielded at the rate of 18.9 bushels per acre, while Fife and bluestem wheats yielded at the rate of 8.3 and 9.5 bushels per acre, respectively, in similar tests.

At Chico, Cal., in 1912, out of 57 selections tested, Alaska wheat ranked forty-third.

In the Judith Basin, Mont., Alaska wheat was sown in the fall of 1908, but winterkilled.

These results, meager as they are, indicate that Alaska wheat is not a valuable wheat in respect to yield in many parts of the central and western United States.

Alaska wheat has been tested for several years in short rows at the Arlington Farm, at Rosslyn, Va., and has done very poorly there. It has never yielded much more than the seed sown and has usually yielded less than this quantity. It is clearly not a valuable wheat for the eastern part of the United States.

Alaska wheat has usually proved a total failure or has given poor results when it has been tried in a small way at the various stations of the United States Department of Agriculture. This and its known inferiority as a milling wheat are responsible for its not being sown in the plats along with other varieties that are being tested. Usually only the better wheats are included in such tests.

This wheat, either under its present name of Alaska or under some of its earlier names, has doubtless been tried on many types of soil in many parts of the United States in the course of the last century. That it has never become established indicates apparently that it is not a valuable variety under any of the conditions where it has been grown. It has remained for promoters to resurrect it time and again and, aided by its striking and unusual appearance, to sell it to the unwary at exorbitant prices. Agricultural literature abounds in instances of this deception.

MILLING TESTS OF ALASKA WHEAT.

Regarding the tests made at the Idaho station,¹ it may be said that milling and baking tests were made of wheat "secured at the warehouse in Juliaetta from the spring and winter Alaska wheat stored there" and of a good grade of Little Club wheat. Without going into details regarding these tests, the following quotation indicates what results were secured:

The results uniformly bear out the laboratory experience that there is very little difference in the baking qualities of flour obtained from the Little Club wheat and that obtained from the Alaska wheat. The Little Club is a soft wheat grown extensively in this part of the State, both as a spring and winter

¹ Data from the following: French, H. T., and Jones, J. S. Alaska wheat investigation. Idaho Agr. Exp. Sta. Bul. 65, 12 p. 1908.

wheat; for milling purposes it would probably be placed about halfway between the best and the poorest milling wheats. We understand that it is considered a good mixer by commercial millers and doubtless much of it is milled accordingly. It should be remembered that all the work mentioned was done upon wheat of this year's crop. It is possible that if samples representing these same lots were taken and ground three months from now and the flour so obtained compared in the same way, more decided differences might be revealed.

A bushel of the Alaska wheat was secured from Mr. Adams's ranch, in 1908, and forwarded to the Grain Standardization Laboratory of the United States Department of Agriculture at Fargo, N. Dak., where it was milled at the experimental mill at the North Dakota Agricultural College. Mr. L. A. Fitz, assistant in grain standardization, reported the results as follows:

A baking test of the three grades of flour obtained was made two days after milling and this was followed by a second test after the flour had aged three weeks. A "standard" or "check" loaf was baked from a hard red spring-wheat flour each day to compare with the particular flour being tested. In all cases 340 grams of flour were used, and the amount of water used was regulated by the absorptive ability of the flour. The same amounts of sugar, salt, and yeast were used in all cases.

The results of the milling tests were as follows:

Laboratory sample No. 243 of Alaska wheat, milled November 10, 1908.

Weight per bushel:		Bran-----per cent--	9.74
Before cleaning---pounds--	59.5	Shorts-----do-----	19.48
After cleaning, scouring,		Total flour-----do-----	70.78
and tempering---pounds--	51.5	Wheat per barrel of flour:	
Quantity milled-----do-----	60.0	Bushels-----	4
Loss in milling-----per cent--	.53	Pounds-----	38

Of the total flour 54.14 per cent was patent flour, 38.76 per cent was first-clear flour, and 7.10 per cent was second-clear flour. This wheat was tempered with water and steam just before grinding. It milled rather peculiarly, reducing to middlings very easily, but was slow to pulverize to flour.

In comparison with the data just given, 16 samples of hard red spring wheat gave the results shown in Table I.

TABLE I.—*Milling test of hard red spring wheat.*

Sixteen samples.	Flour (per cent).		Wheat per barrel of flour.	
	Total.	Patent.	Bushels.	Pounds.
Maximum.....	75.64	78.41	5	0
Minimum.....	69.99	63.52	4	23
Average.....	73.22	74.30	4	34.5

The baking tests of Alaska wheat gave the results shown in Table II.

TABLE II.—*Baking report on sample of Alaska wheat.*

Date and mark.	Water used.	Loaf.		Color.	Texture.	Remarks.
		Weight.	Volume.			
Nov. 12, 1908:	<i>C. c.</i>	<i>Grams.</i>	<i>C. c.</i>	<i>Per cent.</i>		
Standard patent.....	185	459	2,433	97	Good.....	Grayish.
Alaska—						
Patent.....	162	427	1,049	99	Poor.....	Dull and ashy.
First clear.....	172	439	1,195	91	...do.....	
Second clear.....	180	455	1,098	82	...do.....	
Dec. 2, 1908:						
Standard patent.....	184	475	2,368	100	Good.....	Dull.
Alaska—						
Patent.....	183	473	1,155	99	Poor.....	
First clear.....	196	488	1,320	91	Fair.....	
Second clear.....	209	498	1,270	82	...do.....	

The test on November 12 showed that the water absorption was lower, the weight was less, and the volume of loaf was less by half than that of hard spring patent. The color and texture were both quite poor. The test made on December 2 merely showed the improvement which was to be expected as the result of aging.

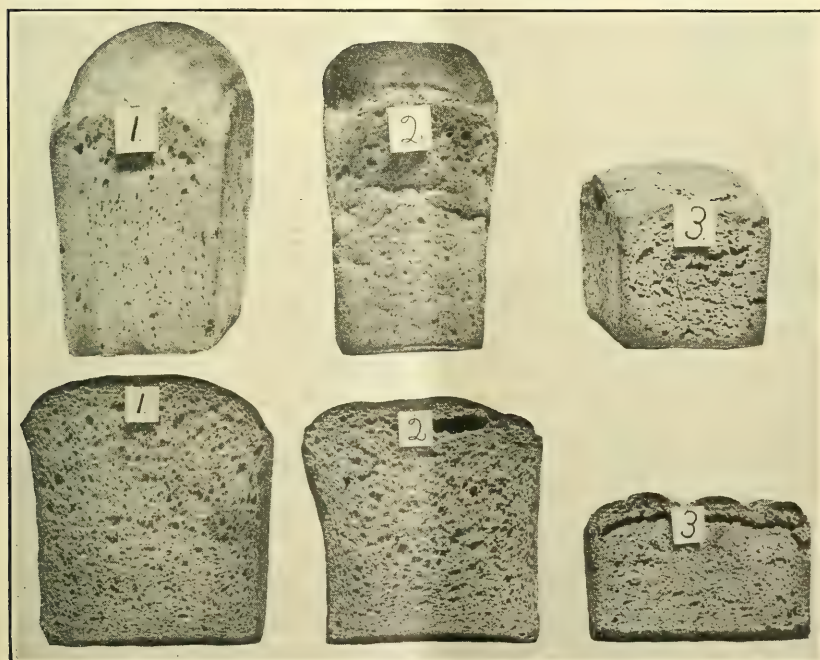


FIG. 2.—Whole loaves (above) and cut loaves (below) baked from patent flours: 1, "Standard," from hard spring wheat; 2, from durum wheat; 3, from Alaska wheat.

Photographs of the loaves obtained in the first baking aid in interpreting the data given. Figure 2 shows whole and cut loaves baked from the patent flour of (1) hard spring wheat, (2) durum wheat, and (3) Alaska wheat. The hard spring loaf is used as the

standard for comparison. Figure 3 shows whole and cut loaves baked from (1) durum first-clear flour, (2) durum second-clear flour, (3) Alaska first-clear flour, and (4) Alaska second-clear flour.

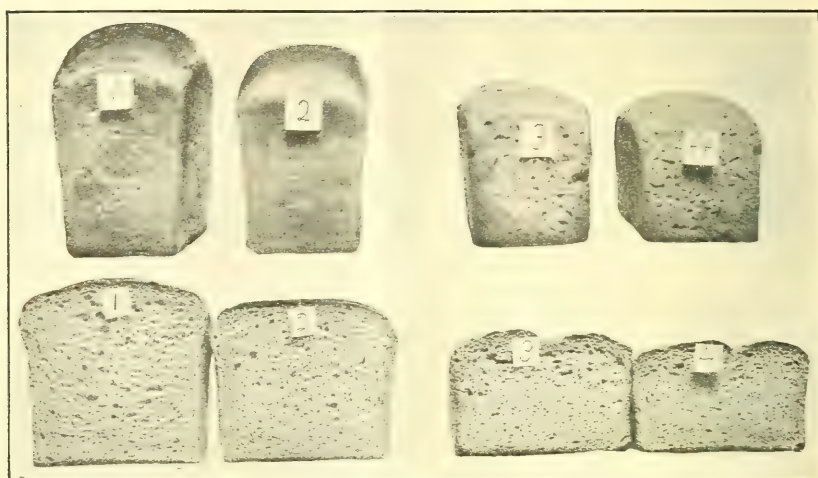


FIG. 3.—Whole loaves (above) and cut loaves (below) baked from first-clear and second-clear flours: 1, First-clear flour from durum wheat; 2, second-clear flour from durum wheat; 3, first-clear flour from Alaska wheat; 4, second-clear flour from Alaska wheat.

The results of these tests show that Alaska wheat is clearly not in the same class and does not deserve to be compared with the hard red spring, the hard red winter, or the durum wheats. The reason for this becomes more apparent on considering the results of the chemical analyses given in Table III.

TABLE III.—*Chemical analyses of flour made from Fife, bluestem, and other wheats, compared with flour made from Alaska wheat.*

Kind of wheat.	Sam- ples aver- aged.	Patent flours.			First-clear flours.			Second-clear flours.		
		Protein (N×5.7).	Gliadin (N×5.7).	Proteinas gliadin.	Protein (N×5.7).	Gliadin (N×5.7).	Proteinas gliadin.	Protein (N×5.7).	Gliadin (N×5.7).	Proteinas gliadin.
Fife and bluestem...	12	12.00	6.70	<i>P. ct.</i> 56.06	12.92	6.95	<i>P. ct.</i> 53.865	13.71	7.10	<i>P. ct.</i> 51.17
Durum.....	13	11.33	6.58	58.35	12.61	6.77	53.98	13.23	6.97	52.91
Preston and winter wheats.....	4	9.60	5.55	58.80	11.03	5.84	53.105	11.16	5.89	53.19
Alaska.....		7.64	3.99	52.24	8.72	4.39	50.313	9.75	4.61	47.39

STONER, OR "MIRACLE," WHEAT.

In the last 10 years a variety of wheat has been widely advertised in the United States under the name "Miracle" wheat. Some very valuable characters have been claimed for it, and for that reason its history, characters, and value, as determined from experiments, are presented in this paper.

The name Miracle is undesirable, so the Department of Agriculture has named this variety Stoner, after the man who first grew it. Other names that have been applied to it are Eden, Forty-to-One, and Marvelous. This is not the only wheat variety that has been called by the name Miracle. Curiously enough, that name has been applied also many times during the last century to the Alaska wheat.

DESCRIPTION OF STONER, OR "MIRACLE," WHEAT.

The wheat here discussed is a variety belonging to the soft red winter wheats. This is the class of wheat commonly grown in the eastern United States from the Atlantic coast to the Mississippi River and beyond. The Stoner wheat has bearded heads (fig. 4), white, hairless chaff, and a medium-sized, rather soft, red kernel. This shows it to belong in the group with Bearded Purple Straw (fig. 5) and Fulcaster (fig. 6), both well-known varieties in the Middle Atlantic States. It grows from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet tall, according to soil and season. It ripens at about the same time as these two varieties which it so closely resembles. Heads of all three varieties are shown in figures 4, 5, and 6. The Stoner (Miracle) wheat is a pure strain; that is, it is descended from a single plant.

HISTORY OF STONER, OR "MIRACLE," WHEAT.

The strain of wheat now known as Stoner originated on the farm of Mr. K. B. Stoner, of Fincastle, near Roanoke, Va. It was first brought to the attention of the United States Department of Agriculture through a letter from Mr. Stoner,¹ dated June 8, 1906.

In the spring of 1904 Mr. Stoner noticed a large bunch of grass in his garden; when headed it proved to be wheat. It had 142 stems, or tillers, and he became impressed with the idea that it was a very wonderful wheat. Just how the kernel of wheat became sown in the garden or from just what variety it came, Mr. Stoner does not know. The Fulcaster variety is commonly grown in that section of Virginia, however, and the Bearded Purple Straw less commonly. It is reasonable to suppose, therefore, that the Stoner wheat is a pure line from one of these varieties, which it so closely resembles.

Mr. Stoner saved the seed and increased it during the two years 1905 and 1906, as shown in his letter. He stated that while he could have his wheat grown at Fincastle on shares, he receiving two-thirds,

¹ In the year 1904 there originated with me a plant of wheat, producing more than a thousandfold. The product of this single grain twice sown (in the years 1904 and 1905) will this harvest (1906), we think, yield sufficient to sow much more than 100 acres. The yield (I suppose) is unprecedented in this or any other country, and for that reason difficult of belief. Possibly this wheat may enable us to successfully compete with the Canadian yield; surely so, if we can grow 2 bushels to their 1.

The drought-injured wheat here, but I have single grains showing a thousandfold, and some near twice that. I think the wheat capable of exceeding 100 bushels to the acre, and think experiments made show that not more than a half bushel should be sown to the acre. The mistake so far has been oversowing.

he wished to get a foothold in Kansas and Iowa as soon as possible. He further asked that an expert be sent to see the wheat and advise regarding its propagation.

The following three chief claims were made for this wheat by the introducer in his various letters of 1906 and in the years following:

- (1) That it would outyield any other variety anywhere.
- (2) That it tillered more freely; that is, that it sent up more stems from one seed than any other variety of wheat.
- (3) That 20 pounds of seed to the acre was enough to produce maximum yields, while other varieties required 8 pecks (120 pounds).

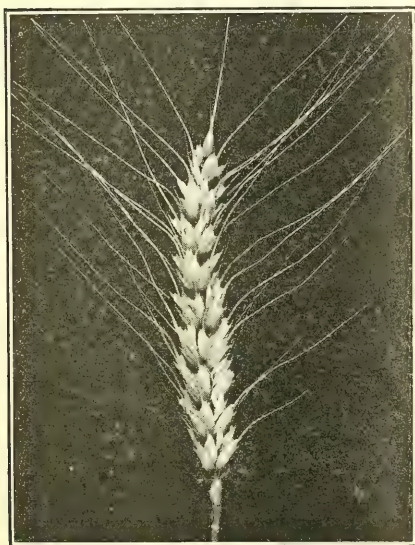


FIG. 4.—Representative head of Stoner, or "Miracle," wheat. (About half natural size.)



FIG. 5.—Representative head of Bearded Purple Straw wheat. (About half natural size.)

In the fall of 1907 an agent of the department visited Mr. Stoner's farm. The visit occurred after harvest, however, and only the stubble field and shocks could be seen. The agent reported that this wheat had been grown in the field for two seasons, but not many definite facts about its value could be obtained.

The report states that "on one farm the yield was 27.5 bushels per acre, which was 3 to 5 bushels more per acre than that of other varieties on the same farm." * * * The Miracle wheat was sown at the rate of only 3 pecks, however, while the other was sown at the rate of 8 pecks per acre. A single test in a single year on different fields, with a difference of 5 pecks per acre in the rate of seeding, is inconclusive.

The report states further that when sown in fields at the 3-peck rate, from 8 to 15 heads were produced on each plant, while the

widely spaced plants in the breeding nursery each produced from 10 to 50 heads. In any case the number varied with the rate of seeding and the fertility of the soil, which is true of all wheats.

EXPLOITATION IN PHILADELPHIA.

Mr. Stoner's desire to have his wheat grown on a large scale in the Mississippi Valley has been noted already. He expected to have about 800 bushels from the harvest of 1907. At some time in the summer of that year a Philadelphia promoter undertook the handling of the wheat and Mr. Stoner wrote to the United States Department of Agriculture that he now could get all the money necessary to promote the growing of his wheat on a large scale.

The plan first proposed by this promoter was to lease a farm in Texas and increase the supply of seed rapidly. It seems that this plan was not carried out.

In the early spring of 1908 the promoter organized a company to exploit this wheat, and a 20-page illustrated circular was issued. Plausible in most of its language, the circular contained several erroneous statements. For instance, it contained what was said to be the report of the Government agent who inspected the fields of Stoner (Miracle)

wheat. The language was so changed, however, as to alter entirely the meaning of the report. The statement that in one field the Miracle wheat had yielded from 3 to 5 bushels more than other varieties on the same farm was made to read "two to three times the yield of other varieties." In like manner the figures for the average number of heads to each plant in the field and in the breeding nursery were greatly exaggerated.

The plan proposed in this circular was to place the wheat with responsible farmers in each county of the wheat-growing States. The farmer receiving the seed was supposed to contract (1) to deposit \$5 for each bushel received, (2) to grow it exclusively for the promoting company, and (3) to receive \$1.25 per bushel for all that he grew and also the return of his original deposits. The wheat was thus to be increased during the two years 1909 and 1910 and then



FIG. 6.—Representative head of Fulcaster wheat. (About half natural size.)

sold in foreign countries, according to the pamphlet. It does not appear, however, that any part of this plan was followed.

PROMOTING "MIRACLE" WHEAT IN CHICAGO.

In the summer of 1908 the financial interest in this wheat seems to have been transferred from the Philadelphia exploiting company to a grain company in Chicago. The details of this transaction are not known, though press items appearing on July 30, 1908, stated that Mr. Stoner had sold the rights to his wheat to western purchasers for a large sum of money and that the wheat would be sown the next season in the great wheat-producing States of the West.

The stated intention of growing this wheat in the West seems to have been carried out at this time, for in the fall of 1908 a controversy developed between the grain company and State officials in Kansas over the merits of the wheat. Nothing further has been heard of this company in connection with this wheat.

PROMOTING "MARVELOUS" WHEAT IN INDIANA.

In 1908 Mr. Stoner sold a quantity of his wheat to a seed company in Indiana. By them it was renamed "Marvelous" wheat and advertised in extravagant terms as a wonderful variety. This company is still advertising the Stoner wheat under the name given above.

PROMOTING "MIRACLE" WHEAT IN BROOKLYN.

In the summer of 1911 an organization in Brooklyn began advertising Miracle wheat at \$1 a pound in its own publication. Two or three years previously it had quoted a portion of the pamphlet published by the exploiting company of Philadelphia.

In the summer of 1912 this organization issued a four-page special publication, of full newspaper size, the entire first page of which was an advertisement of the wonders of Miracle wheat and spineless cactus. The headlines read: "Spineless cactus—Miracle wheat—Millionaires and vast irrigation schemes are Bible propositions." The seven columns of text were to the effect that these two crops are creations in fulfillment of biblical prophecy. By means of an enormous irrigation project, financed by Wall Street millionaires, all the arid West was to be converted into vast fields of wheat and cactus.

THE STONER SEED WHEAT COMPANY.

During these years when various organizations were exploiting this wheat, the introducer continued to sell seed. There is no reason to think that he had any connection with any of these organizations.

In June, 1911, he published an illustrated advertising booklet to increase the demand for the seed. Testimonials from 12 growers are printed therein, but only one gives an actual yield from a piece of

ground of stated size. That one got 12 bushels from a half acre, or at the rate of 24 bushels to the acre. Part of the others tell what they think their wheat will yield. The rest tell what their 2-pound and 4-pound lots yielded without stating the size of the plat on which these were sown.

The statement is repeated that this wheat will yield more when sown at the rate of 2 or 3 pecks per acre than when sown at 8 pecks, or than other wheats will yield when sown at the usual rate. References are made to the size of the plants and the large number of grains produced by them when widely spaced in the nursery. Definite statements that prove in any way the superior value of the wheat was not found in the pamphlet.

The pamphlet states that previously the wheat had been selling at the rate of \$1.25 a pound, with 4 pounds the largest quantity sold to any one person. At this time, however, the price was reduced to \$5 a bushel.

In recent correspondence Mr. Stoner has stated that during 1911 and 1912 the demand for the seed was not very large. He states further, however, that interest in the crop is increasing rapidly and that during the last two seasons sales have been numerous. Previously much of the crop had been milled for lack of a demand for it as seed wheat.

Mr. Stoner still claims that his wheat is a superior yielder. He still claims that it will make better yields from thin seeding than other wheats will from thick seeding. He even advises using less than a peck of seed to the acre and closing each alternate seed tube in the drill.

EXPERIMENTAL DATA ON STONER (MIRACLE) WHEAT.

The Stoner (Miracle) wheat has been tested at several of the State experiment stations and by the United States Department of Agriculture. These tests have been made in comparison with other varieties, and the best approved methods have been used without favor or bias. Actual yield tests in comparison with other varieties, tests of the effect of different rates of seeding, and tests of the tillering of the variety are therefore now available.

YIELDS OF STONER WHEAT IN COMPARISON WITH OTHER VARIETIES.

TESTS AT THE MARYLAND AGRICULTURAL EXPERIMENT STATION.¹

At the Maryland Agricultural Experiment Station the Stoner (Miracle) wheat has been tested since 1912, in cooperation with the United States Department of Agriculture, in one-twentieth acre plats, with the results shown in Table IV.

¹For further data concerning the tests made at College Park, Md., and at Arlington Farm, Rosslyn, Va., see Stanton, T. R., *Cereal Experiments in Maryland and Virginia*, U. S. Dept. Agr., Bul. No. 336, 52 p., 6 fig. 1916.

TABLE IV.—Yield of Stoner (Miracle) wheat tested at College Park, Md., at different rates of seeding, in comparison with other varieties seeded at the rate of 6 pecks per acre.

Crop year.	Yield per acre of Stoner wheat at different rates of seeding.				Best yield obtained from other varieties.	Number of varieties tested.	Rank of best plat of Stoner wheat.
	2 pecks.		6 pecks.				
	Grain.	Straw.	Grain.	Straw.			
	<i>Bushels.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>	<i>Bushels.</i>		
1912.....	22.67	4,540	27.87	5,740	29.20	52	5
1913.....	12.53	1,948	16.20	1,988	28.33	42	34
1914.....	34.23	3,686	32.33	3,740	41.87	41	31
Average.....	23.14	3,391	25.47	3,823	.....	.....	.....

From the data given in Table IV it is seen that better yields of grain were obtained from the 6-peck seeding in two years out of three, and the average for the three years is 2.33 bushels larger for the heavier seeding. The 6-peck per acre seeding has resulted in the better yield of straw for each year of the test. It is further seen that Stoner (Miracle) wheat is not as good a yielding wheat as many others that are being grown. In the year 1912, when it did best, compared with other varieties, it was fifth in yield among the 52 varieties tested and fell behind the best variety 1.33 bushels. In 1913 it was thirty-fourth among the 42 varieties tested, and in 1914, thirty-first among the 41 varieties tested.

TESTS AT ARLINGTON FARM.

Tests similar to those made at the Maryland Agricultural Experiment Station have been made at the Arlington Farm, Rosslyn, Va., by the Office of Cereal Investigations of the United States Department of Agriculture. The wheat used in these tests was developed from a small amount of seed presented to the office by Mr. K. B. Stoner in 1907. The tests here have been carried on for four years, 1911 to 1914, inclusive. The varieties were grown in one-tenth or one-twentieth acre plats and were seeded at the rate of 6 pecks per acre. The results are shown in Table V.

TABLE V.—Yield of Stoner (Miracle) wheat tested at Arlington Farm, Rosslyn, Va., in comparison with other varieties in similar plats.

Crop year.	Yield per acre of Stoner wheat.	Best yield obtained from other varieties and strains.	Number of varieties and strains tested.	Rank of Stoner wheat.
	<i>Bushels.</i>	<i>Bushels.</i>		
1911.....	25.20	32.30	34	11
1912.....	30.17	37.17	37	16
1913.....	22.00	34.70	41	18
1914.....	32.30	38.20	36	6
Average.....	27.42			

It is seen from the results here presented that this wheat has never ranked better than sixth in yield, and was then 5.9 bushels under the best variety tested. It has always ranked among the better half, but only once among the best fourth of the varieties tested.

The 30 varieties and strains with which the Stoner (Miracle) wheat has been compared during the entire four years it has been grown, 1911 to 1914, inclusive, in the plat tests at Arlington Farm and the yields of these are shown in Table VI. Varieties that have not been grown in these comparative tests for the entire four years are omitted from the table. The varieties are arranged in the table according to average yield for the four years. It is here shown that this wheat has ranked tenth in the 31 kinds in average yield for this period, and has yielded 6.55 bushels less than the best variety.

TABLE VI.—Yield of the varieties of winter wheat grown each year at Arlington Farm, Rosslyn, Va., 1911 to 1914, inclusive.

C. I. No.	Variety.	Yield per acre (bushels).				
		1911	1912	1913	1914	Average.
1915	Purple Straw.....	25.80	37.17	34.70	38.20	33.97
1733	Dawson Golden Chaff.....	24.80	36.00	25.80	35.20	30.45
1957	Purple Straw.....	31.30	33.08	24.20	30.80	29.84
1945	Lancaster.....	28.80	29.08	26.50	33.30	29.42
1979	Poole.....	24.30	31.92	26.60	29.20	28.00
1744	Genesee Giant.....	20.30	30.67	28.40	32.50	27.97
1912	Missouri Bluestem.....	28.60	32.08	22.50	28.70	27.97
1942	Bearded Winter Fife.....	26.60	36.42	24.90	23.30	27.80
1930	Rocky Mountain.....	25.80	31.50	26.20	26.30	27.45
2980	Stoner (Miracle).....	25.20	30.17	22.00	32.30	27.42
1949	Maryland Flint.....	32.30	29.08	23.50	23.70	27.14
1923	Fultz.....	25.20	31.22	22.70	29.10	27.05
1973	New Amber Longberry.....	26.50	29.50	22.70	29.50	27.05
2008	Mammoth Red.....	25.30	29.20	25.20	28.20	26.97
3617	Hybrid.....	21.70	34.67	21.80	27.80	26.49
1981	Dietz.....	25.20	28.34	21.10	28.20	25.71
3277	Virginia.....	24.50	35.15	21.00	21.50	25.54
1969	Michigan Amber.....	28.00	28.83	21.00	21.00	24.71
3614	Hybrid.....	16.80	30.07	19.20	31.30	24.34
3608	do.....	21.20	31.67	19.07	25.30	24.31
1974	Martin Amber.....	21.90	31.50	20.00	23.70	24.27
3616	Hybrid.....	20.00	29.67	16.10	31.00	24.19
1933	Jones Winter Fife.....	22.80	24.00	24.70	24.70	24.05
3618	Hybrid.....	22.50	30.55	20.80	22.20	24.01
1911	Bearded Purple Straw.....	20.10	28.67	23.20	22.30	23.57
1980	Fultz-Mediterranean.....	21.70	28.83	19.20	22.50	23.06
3610	Hybrid.....	16.70	29.20	22.00	21.00	22.22
3609	do.....	14.70	32.53	18.01	23.30	22.13
3613	do.....	12.00	22.27	19.70	31.20	21.29
3611	do.....	20.70	21.60	15.70	24.70	20.67
3612	do.....	13.80	20.27	19.50	24.50	19.52

¹ Used as the check; the figures given are the average of the yields from several plats.

TESTS AT NEPHI, UTAH.

Stoner (Miracle) wheat was tested at Nephi, Utah, in 1911, by the United States Department of Agriculture in cooperation with the Utah Agricultural Experiment Station, in one-twentieth acre plats, in comparison with several other varieties. The results are shown in Table VII. In this test of seven varieties, this wheat ranked sixth in yield, producing 26.7 bushels, or 11.4 bushels less than the best yielding variety.

TABLE VII.—Yield of wheat grown at Nephi, Utah, in 1911 from pedigreed seed of 1910.

Variety.	C. I. No.	Class.	Yield per acre.
			<i>Bushels.</i>
Odessa.....	3274-1	Soft winter.....	38.1
Kharkof.....	1583-2	Hard winter.....	31.0
Alberta Red.....	2979-17	do.....	29.3
Turkey.....	2998-1	do.....	27.7
Do.....	3055-13	do.....	27.3
Stoner.....	2980	Soft winter.....	26.7
Turkey.....	1571-2	Hard winter.....	18.0
Average.....			28.3

RATE-OF-SEEDING TESTS.

Rate-of-seeding tests have been conducted on the Arlington Farm by the United States Department of Agriculture with the Stoner (Miracle) wheat for three years, it having been first included in these tests in the sowings made in the fall of 1911. In these tests this wheat was compared in the first year with seven other varieties, four of which are well-known sorts commonly grown among farmers. In the two succeeding years it has been compared with three of these well-known sorts. The names of the varieties used and the yields for the different rates of seeding are given in Table VIII, only those varieties being included which have been used throughout the entire 3-year period. In 1912 no seeding of less than 4 pecks per acre was made of any of the varieties. In the succeeding two years seedings of 2, 3, 4, 5, 6, 7, and 8 pecks per acre were made. The plats were one-twentieth of an acre in size in 1912, and the tests were not replicated, but in 1914 the size of the plats was reduced to one-fortieth of an acre, and the sowings were made in duplicate and the results averaged.

These results show that the best yield of Stoner wheat has been obtained by sowing 4 pecks per acre. When 2 pecks were sown in the two years 1913 and 1914, 22.15 bushels were harvested. In these same years 24.5 bushels were harvested from 3 pecks sown and 24.95 from 4 pecks. From sowings of 5, 6, 7, and 8 pecks, less quantities were harvested than from the 3-peck or 4-peck seedings, but in each case more than from the 2-peck seeding. An addition of 2 pecks to the quantity sown has increased the yield over the 2-peck sowing an average of 2.8 bushels per acre for the two years. Including the year 1912 and averaging for only the 4, 5, and 6 peck seedings, the best yield was again obtained by sowing 4 pecks, the yield here, 26.52 bushels, being larger than that secured from sowing either 5 pecks or 6 pecks per acre. Smaller or larger sowings were not made in the year 1912.

TABLE VIII.—*Yield of Stoner (Miracle) wheat and other varieties in comparative rate-of-seeding test at Arlington Farm, Rosslyn, Va.*

Variety and year.	Yield per acre (bushels) at different rates of seeding.						
	2 pecks.	3 pecks.	4 pecks.	5 pecks.	6 pecks.	7 pecks.	8 pecks.
Stoner (Miracle):							
1912.....			29.67	32.22	30.17		
1913.....	17.40	18.30	17.10	17.50	14.70	14.50	16.00
1914.....	26.90	30.70	32.80	28.90	29.70	30.90	29.80
Average 1913-14.....	22.15	24.50	24.95	23.20	22.20	22.70	22.90
Average 1912-14.....			26.52	26.21	24.86		
Dietz:							
1912.....			28.00	24.50	22.67		
1913.....	18.90	19.90	16.80	18.70	19.40	17.40	19.70
1914.....	26.70	30.00	29.50	27.80	29.70	30.60	32.50
Average 1913-14.....	22.80	24.95	23.15	23.25	24.55	24.00	26.10
Average 1912-14.....			24.77	23.67	23.93		
Fultz:							
1912.....			32.55	32.42	31.22		
1913.....	19.10	22.70	24.70	24.60	24.00	21.30	24.80
1914.....	29.70	33.00	39.00	37.70	36.20	37.40	37.90
Average 1913-14.....	24.40	27.85	31.85	31.15	30.10	29.35	31.35
Average 1912-14.....			32.08	31.57	30.47		
Martin Amber:							
1912.....			34.92	31.83	28.83		
1913.....	18.40	19.70	19.00	17.20	17.40	12.40	14.70
1914.....	22.60	27.00	26.00	24.90	27.80	25.60	23.90
Average 1913-14.....	20.50	23.35	22.50	21.05	22.60	19.00	19.30
Average 1912-14.....			26.64	24.64	24.68		
Average of all:							
Average 1913-14.....	22.46	25.16	25.61	24.66	24.86	23.76	24.91
Average 1912-14.....			27.50	26.52	25.98		

When these results are compared with those for the other varieties used, it is seen that as an average for the two years 1913 and 1914 the largest gross yields were obtained from sowing 8 pecks of Dietz, 4 pecks of Fultz, and 3 pecks of Martin Amber. On account of the larger quantity of seed used in sowing 8 pecks, the largest net return from the Dietz was from the 3-peck seeding. The largest net returns from the other varieties were from the same seedings mentioned above. Including the year 1912 and averaging for only the 4, 5, and 6 peck seedings, the largest net and gross returns were obtained for the three years 1912-1914 in every case from the smallest quantity; that is, from the 4-peck seeding.

When all varieties are averaged both for the two years, 1913-1914, and for the years, 1912-1914, the best gross and net yields were obtained from the 4-peck seeding. The 4-peck seeding yielded 0.45 bushel more than the 3-peck and 3.15 bushels more than the 2-peck seeding.

It must be concluded that Stoner wheat does not differ from the other varieties tested in requiring less seed per acre, and also that 2 pecks are not sufficient from which to obtain maximum yields.

It should be said in connection with these tests that these wheats were drilled in fertile soil in a well-prepared seed bed. More seed

of all these varieties would probably be required where conditions are not so favorable.

TILLERING POWER OF STONER (MIRACLE) WHEAT.

Tests to determine the tillering power of Stoner (Miracle) wheat were made at Arlington Farm by sowing, in both 1912 and 1913, individual kernels of this variety and of three standard varieties, each kernel being given plenty of room for maximum development. These kernels were sown 6 inches apart in rows 1 foot apart and 5 feet long, in uniform soil, the order of sowing being that given in Table IX. All varieties were grown under identical conditions on small adjacent plats of land.

TABLE IX.—*Tillering power of Stoner (Miracle) wheat in comparison with other varieties at Arlington Farm, Rosslyn, Va.*

Number of heads per plant.	Number of plants, crop of 1913.				Number of plants, crop of 1914.			
	Fultz.	Dietz.	Stoner.	Martin Amber.	Fultz.	Dietz.	Stoner.	Martin Amber.
1.....			2	1	1		1	
2.....				5				1
3.....	2	1	1	1				2
4.....	1	3	4	3	2	1		3
5.....	2	3	2	1	5	3		2
6.....	6	4	6	3	4	1		4
7.....	1	3	4	4	7	6		2
8.....	5	2	1	1	12	11		6
9.....	3	1	4	3	11	11		20
10.....	6	3	4	3	10	10		12
11.....	8	3	2	5	14	13		11
12.....	5	3	4	3	16	17		5
13.....	6	7	1	1	3	14		6
14.....	4	4	2	3	4	2		6
15.....	4	1		2	2	3		2
16.....	2	1	2		2			2
17.....		1		1	1	1		1
18.....	1		2		1			
19.....	1	1						
20.....					1	1		
21.....		1						
31.....				1				
Total plants.....	57	42	41	41	97	94	92	91
Average number of culms per plant.....	10.5	10.3	8.7	9.0	10.1	10.4	9.6	12.2

Table IX shows that in 1913 the 41 plants of Stoner wheat produced an average of 8.7 culms to the plant. This is the smallest number produced by the plants of any of the varieties used, Martin Amber producing 9 culms, Dietz 10.3, and Fultz 10.5.

The results for 1914 are similar to those of the previous year in this respect, that the plants of Stoner wheat again produced the smallest average number of culms, there being in this year 9.6 to the plant of this variety. Fultz produced 10.1, Dietz 10.4, and Martin Amber 12.2. The tests for these two years indicate, then, that Stoner is the poorest of these four wheats in tillering power. These results also show that in neither year was there a larger number of culms than 18 produced by any plant of the Stoner wheat, while there is a total of ten plants of the other varieties in the two years which produced more than 18 culms each.

Similar tests to determine the tillering power of Stoner (Miracle) wheat were conducted in the years 1909, 1911, and 1912 at Nephi, Utah, by the United States Department of Agriculture in cooperation with the Utah Agricultural Experiment Station. The sowing was in head rows 10 feet long and 1 foot apart, the seeds being placed 4 inches apart in the row. The results are shown in Table X.

The average number of culms produced by the plants of this wheat in the three years is 11. It is third in rank among the nine varieties tested for all or part of the time, but it produced eight culms less than the best tillering variety, the Turkey, which produced an average of 19 culms per plant for the three years. In no year was the Stoner wheat highest in culms produced. In yield this wheat ranks third as an average for all varieties tested for the three years. A yield test in head rows, however, is inclusive. Yield tests in one-twentieth acre plats at Nephi have been previously reported.

TABLE X.—*Tillering power and yield of Stoner (Miracle) wheat and eight other wheats at Nephi, Utah, in the years 1909, 1911, and 1912.*

C. I. No.	Variety.	Class.	Average number of heads per plant.				Yield per row (grams).			
			1909	1911	1912	Average.	1909	1911	1912	Average.
3055-13.....	Turkey.....	Hard red winter....	13	25	18	19	210	181	148	180
2997-5.....	Koffoid.....	Soft white winter....	9	16	10	12	253	265	157	225
2996-2.....	Gold Coin.....	do.....	7	16	7	10	191	165	129	162
2980.....	Miracle.....	Semihard red winter. ter.	7	16	11	11	213	186	116	172
	Alaska.....	Soft white winter (or spring).	3			3	47			47
2100.....	Black Don.....	Durum.....	5	5		5	56	25		41
3001-1.....	Silver Club.....	Soft winter club....	7			7	211			211
2398-1.....	Galgals.....	Soft white spring....	6			6	144			144
2934-1.....	Durum.....	Durum.....	4	3	3	3				
Average..			6.8	13.5	9.8	8.2	165.6	164.4	137.5	147.7

GENERAL TESTS BY STATE EXPERIMENT STATIONS.

TESTS IN KENTUCKY.

The following results of tests of Miracle wheat made at the Kentucky Agricultural Experiment Station are published in Bulletin 155 of that station:

Seed sown per acre.	Yield per acre in 1911.	
	Miracle.	Harvest King.
	Bushels.	Bushels.
2 pecks.....	31.3	
3 pecks.....	32.7	
4 pecks.....	34.7	35.0
5 pecks.....	35.3	35.0
6 pecks.....	36.7	34.7
7 pecks.....		36.3
8 pecks.....		25.0

The party furnishing Miracle wheat recommended 2 pecks per acre, claiming great stooling power for it.

Subsequent results obtained at the Kentucky station are given in the letter below from E. J. Kinney, assistant agronomist of that station:

I beg to say that we did not continue the experiments recorded in 1911 in Bulletin 155 any longer than the one year. The Miracle wheat showed no greater propensities for stooling than any of the standard varieties of wheat, and there seemed no necessity for carrying the experiment any farther. So far as moisture was concerned, 1911 was a very normal season; in fact, better than a normal season, according to my records, so that the thinner sown wheat had the best opportunity to stool.

In 1912 Miracle wheat yielded only 22.5 bushels, as compared with 28.1 bushels for Fulcaster and an average of 30 bushels for a standard Fultz variety; 1912 was a very hard winter, and only the hardiest varieties of wheat came through in good shape.

In 1913 Miracle yielded 28.7 bushels per acre, or a corrected yield according to check plats of 32 bushels, as compared with an average of the check plats of 32.8. Fulcaster the same year gave a corrected yield of 33.9 bushels per acre.

In 1914 Miracle gave a corrected yield of 26.76 bushels, as compared with an average check-plot yield, which was Fultz, of 32.98 bushels per acre. In all these cases, the crops were planted at the same time, in the same field, with the same preparation of soil and the same rate of seeding.

In 1914 a farmer brought in a variety of wheat which he said was sold to him as Marvelous, and which I imagined and still believe is the same as Miracle. It was reported as giving a full yield with a light seeding; say, 2 pecks. I planted a plot of this at the rate of 6 pecks per acre and one at the rate of 2 pecks per acre, the corrected yield being 31.17 bushels for the 6 pecks per acre rate of seeding and 24.46 for the 2 pecks rate of seeding.

I do not see that Miracle or Marvelous stooled any more than a standard variety of wheat, such as Fulcaster or other varieties. Certainly, in all cases where we have tested these varieties with the proclaimed stooling characters, the thicker seeding has given decidedly the heavier yield.

TESTS IN PENNSYLVANIA.

The Pennsylvania Agricultural Experiment Station sowed the Stoner (Miracle) wheat at two rates in the fall of 1912. The yields in 1913 are given in Bulletin 125 of that station, and are as follows:

Stoner (Miracle) wheat.	Actual yield.		Corrected yield.	
	Grain.	Straw.	Grain.	Straw.
Seeded at—	<i>Bushels.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
2 bushels per acre.....	33.6	4,665	30.8	4,473
1 bushel per acre.....	28.6	3,350	25.5	3,419

The increased yield of 5 bushels resulting from the sowing of 1 bushel more of seed is certainly worth the increased expense for seed.

Regarding subsequent tests made of this variety by the Pennsylvania Agricultural Experiment Station, the following extract from a letter received from Charles F. Noll, assistant professor of experimental agronomy, is self-explanatory:

Replying to your letter of May 28 in regard to Miracle wheat, we seeded this variety in 1914 only at the rate of 2 bushels per acre, which is our usual rate of seeding the variety testing plats. I have averaged the yields of our named varieties for the years 1913-14, and find that Miracle gave us a yield of 32.5 bushels of grain and 3,772 pounds of straw per acre. In yield of grain for these two years, it has ranked eighth, and fifth in yield of straw. For our conditions it is a good variety of wheat, but there is nothing remarkable about its productiveness or its tillering.

TESTS IN INDIANA.

The Miracle wheat under the name of Marvelous has been tested by the Indiana Agricultural Experiment Station at Lafayette, Ind., and the results secured are given in the following extract from a letter from C. O. Cromer, associate in crops at that place:

Last year (1914) was the only year in which we have secured any data on this wheat (Marvelous). The other years that we sowed it the winter was too severe for it. In looking up our records I find that in comparison with the Michigan Amber, the variety which we have used as our check for a number of years, the Marvelous wheat stands as follows: The Michigan Amber at 3 pecks per acre produced 10.9 bushels. The Marvelous produced 4.8 bushels. The Michigan Amber at 6 pecks per acre produced practically the same as the Michigan Amber at 3 pecks, while the Marvelous at 6 pecks produced 5.5 bushels. The spring survival of the Michigan Amber was 85 per cent; that of the Marvelous was 45 per cent. A much larger percentage of the Marvelous wheat lodged than was true of the Michigan Amber. The straw of the Marvelous is a little stiffer, however, as a rule. The Michigan Amber, according to our data of last year, was on the average 4 inches taller than the Marvelous wheat and ripened two days earlier.

CONCLUSIONS.

The reader should remember these facts about the branch-headed wheat known as Alaska, Seven-Headed, Mummy, Egyptian, or by some other name: (1) That it has been used in this country very often as a means of deceiving people and very seldom as a farm crop; (2) that it has failed to produce even fair yields when tried in many parts of the country, and has never been known to produce extraordinary yields; (3) that it is not as good a milling wheat as many other widely-grown varieties, some of which are much better adapted to any given location; (4) that the branched head is not a sign of superior yielding power.

Stoner wheat does not differ essentially in value from many other wheats now being widely grown in the eastern half of the United States. It is not as good as some and is somewhat better than others. The class of wheat (soft red winter) to which it belongs is adapted

to the eastern United States, but the variety itself is only of average value. It is not adapted to dry lands.

The claims made by the originator of Stoner (Miracle) wheat and by those who have exploited it are not substantiated by the experimental results reported above.

It was claimed that it would outyield any other variety anywhere. In the tests it has never outyielded anywhere all other varieties with which compared, and many other varieties have surpassed it in yield.

It was claimed that it tillered more freely than other varieties. The tests show that other commonly grown varieties have exceeded it in number of culms to the plant produced wherever grown in comparative tests.

It was claimed that 20 or 30 pounds of seed per acre were sufficient for maximum yields. The tests show that better yields are obtained from it when sown at higher rates to the acre.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 358

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

April 12, 1916

STUDIES OF THE MEXICAN COTTON BOLL WEEVIL IN THE MISSISSIPPI VALLEY.

By R. W. HOWE.

Entomological Assistant, Southern Field Crop Insect Investigations.

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INTRODUCTION.

Shortly after 1892, when the Mexican cotton-boll weevil (*Anthonomus grandis* Boh.) invaded Texas on its northward and eastward journey and its extreme importance was seen, complete data were secured on the various biological functions. In recent years, however, numerous observations have shown that, under new climatic and other environmental conditions to which the weevil has been subjected in its spread, changes have been taking place in many of these functions. In addition, a new variety of the boll weevil has been found breeding in a wild cotton (*Thurberia thespesioides*) occurring in the mountain ranges of southeastern Arizona, and this weevil (which has been described as *Anthonomus grandis thurberiae* Pierce) has been found to possess habits which differ in many ways from those of its near relative on cultivated cotton. Consequently, it has been necessary to repeat many studies under both the old and the new conditions and to include the new variety. In this way the

NOTE.—This bulletin is of interest to entomologists in the cotton belt.

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extent and trend of the variations may be determined and a more definite knowledge of what to expect in the future may be obtained. As every phase of the control of the weevil is based upon biological facts, life-history studies have a very direct economic bearing upon the boll-weevil problem.

During 1913, 1914, and 1915 the writer conducted a number of studies on the biology of the weevil at the Delta Boll Weevil Laboratory at Tallulah,¹ La. The present paper deals largely with the results of these two years' observations, but before detailing these it is probably best to review very briefly the times and conditions under which the similar studies have been conducted.

The earliest work was that at Victoria, Tex., in 1902 and 1903, the results being published early in 1904.² This was followed by similar investigations at the same place during 1904, and the results of these studies were included in a bulletin issued in 1905.³

During 1910 similar investigations were conducted at Tallulah, La., and the results were published in 1911.⁴

Then, in 1912, these studies and such others as had been made elsewhere were brought together in a large bulletin issued in 1912.⁵

During 1913 another series of studies was conducted at Victoria, Tex., to check those which had been made at the same place 10 years earlier. It was found that the weevils had made a number of important changes in their life history, principal among these being a much greater adaptability to plants other than cotton as food. The biology of the Arizona *Thurberia* weevil was also studied, and this variety was hybridized with the Texas cotton weevils. The results of these studies are included in three papers.⁶

In 1914 the life history and habits of the Arizona weevil were studied under natural conditions in the mountains near Tucson, Ariz. These studies are discussed in two papers.⁷

¹ The writer wishes to acknowledge his indebtedness to Mr. E. K. Bynum for assistance in the work of 1915.

² Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bur. Ent. Bul. 45, 116 p., 16 pl., 6 fig., 1904.

³ Hunter, W. D., and Hinds, W. E. The Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bur. Ent. Bul. 51, 181 p., 23 pl., 8 fig., 1905.

⁴ Cushman, R. A. Studies in the biology of the boll weevil in the Mississippi Delta region of Louisiana. *In* Jour. Econ. Ent., v. 4, no. 5, 1911. p. 432-448.

⁵ Hunter, W. D., and Pierce, W. D. Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bur. Ent. Bul. 114, 188 p., 22 pl., 34 fig., 1912.

⁶ Coad, B. R., and Pierce, W. D. Studies of the Arizona *Thurberia* weevil on cotton in Texas. *Proc. Wash. Ent. Soc.*, v. 16, no. 1. p. 23-28. 1914.

Coad, B. R. Feeding habits of the boll weevil on plants other than cotton. U. S. Dept. Agr. Jour. Agr. Res., v. 2, no. 3, p. 235-245. 1914.

Coad, B. R. Recent studies of the Mexican Cotton Boll Weevil. U. S. Dept. Agr. Bul. 231, 34 p., 1 fig. 1915.

⁷ Coad, B. R. Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. U. S. Dept. Agr. Bul. 233, 12 p., 4 pl. 1915.

Coad, B. R. Studies on the Biology of the Arizona Wild Cotton Weevil. U. S. Dept. Agr. Bul. 344, 23 p., 2 pl., 1 fig. 1916.

Thus it is seen that these studies embrace a wide range of time and conditions. In fact, the conditions of humidity, rainfall, temperature, altitude, soil, etc., include practically all extremes found in the cotton belt.

The various breeding series of 1914 and 1915 were conducted in a large insectary located at the Delta Laboratory, Delta, La. (fig. 1). This was provided with screen sides to furnish free air circulation, and the curtains were so arranged that the direct sunshine did not reach any of the breeding cages. Practically all of the breeding

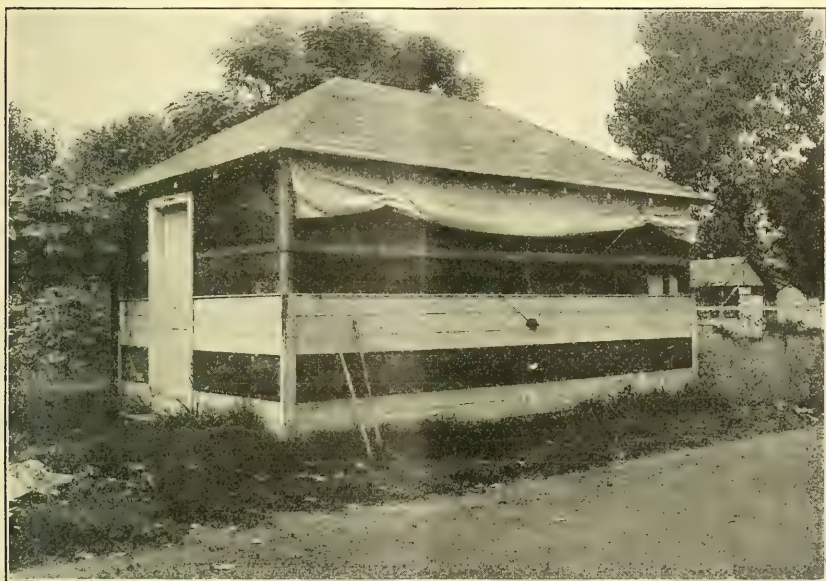


FIG. 1.—Insectary at the laboratory at Delta, La., for studies on the boll weevil. (Original.)

work was done in glass tumblers partially filled with moist sand and covered with a double thickness of cheesecloth.

LONGEVITY OF ADULT WEEVILS.

A considerable number of observations were made on the adult longevity on different foods. The data secured are separated by seasons.

SEASONS OF 1913 AND 1914.

Table I gives the observations made during the seasons of 1913 and 1914. The maximum record of longevity in 1914 was made by a first-generation female fed on cotton squares. This female emerged July 13 and died October 28, with a total life of 107 days. The maximum length of life of male weevils fed on cotton squares was 100 days; this individual emerging July 14 and dying October 22. The average longevity was 9.8 days on cotton leaves, 10.5 days on cotton bolls, and 46.3 days on cotton squares.

TABLE I.—*Duration of life of boll weevils. Observations of 1913-14.*VARIETY *GRANDIS* WITHOUT NORMAL FOOD.

Season and period.	Food.	No. of weevils.	Weevil days.	Average longevity.	Maximum longevity.	Remarks.
1913.				<i>Days.</i>	<i>Days.</i>	
Sept. 24 to Oct. 7....	Hibiscus leaves..	4	24	6.0	13	In paper bags on plants.
Sept. 24 to Oct. 10....	Hibiscus bolls....	4	25	6.3	16	Do.
Do.	Hibiscus leaves, flowers, and bolls.	4	46	11.5	16	Do.
Sept. 24 to Oct. 9....	Okra buds and fruit.	8	44	5.5	15	Do.
Sept. 24 to Oct. 12....	Okra fruit.....	8	75	9.4	18.	Do.
Sept. 24 to Oct. 8....	Okra leaves.....	4	26	6.5	14	Do.
Sept. 24 to Oct. 10....	Thurberia leaves	4	42	10.5	16	Do.
Sept. 24 to Oct. 4....	Thurberia tips and buds.	4	34	8.5	10	Do.
Sept. 24 to Oct. 8....	Thurberia squares.	4	29	7.3	14	Do.
Total longevity on malvaceous plants..		44	345	7.8	18	

VARIETY *GRANDIS* WITH NORMAL FOOD.

1914.						
Aug. 6 to —.....	Cotton leaves....	40	390	9.8	17	In glass tumblers.
July 15 to Aug. 1....	Cotton bolls....	20	210	10.5	16	Do.
June 3 to Oct. 28....	Cotton squares..	24	1,106	46	107	Females in glass tumblers.
June 13 to Oct. 28....	do.....	24	1,118	46.6	100	Males in glass tumblers.
Total on normal food.....		108	2,824	26.1	107	

In the abnormal food studies the weevils lived an average of 6 days on Hibiscus leaves; 11.5 days on Hibiscus leaves, flowers, and fruit; 6.25 days on Hibiscus tips; 6.5 days on okra leaves; 9.4 days on okra fruit; 11 days on okra leaves, flowers, and fruit; 10.5 days on Thurberia leaves; 8.5 days on Thurberia tips and buds, and 7.3 days on Thurberia squares. These records are all low, probably due to the experimental methods, as the weevils were all placed upon the food in paper bags and later observations show that the method apparently causes an early death.

SEASON OF 1915.

The studies of 1915 compare the longevity of *grandis* weevils on moist sand with no food, on moist sand with okra and Hibiscus, on moist sand with different parts of the cotton, and also *thurberiae*, on moist sand with okra, with cotton bolls, and with cotton squares. The species of Hibiscus used were *H. militaris* and *H. moscheutos*. The results are given in Table II.

TABLE II.—Duration of life of boll weevils. Observations of 1915.

VARIETY GRANDIS WITHOUT NORMAL FOOD.

Date.	Substance provided.	Males.				Females.				Both sexes.		Notes on weevils.
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
June 9.....	No food.....	54	148	<i>Days.</i> 2.77	<i>Dys</i> 40	9	36	4.0	15	40	2.9	Hibernated weevils.
June 8.....	do.....	30	162	5.4	10	30	167	5.57	11	11	5.48	Collected in field.
June 29.....	do.....	20	40	2.0	6	20	48	2.4	5	6	2.20	Hibernated.
Sept. 8.....	do.....	12	27	2.25	3	12	33	2.75	3	3	2.50	Bred.
Aug. 13.....	do.....	20	63	3.15	10	20	69	3.45	10	10	3.30	Do.
Total without food.....		136	440	3.24	40	91	353	3.88	15	40	3.49	
July 2.....	Young okra fruit	6	22	3.67	6	6	27	4.5	7	7	4.1	Bred from squares collected in field.
July 22.....	do.....	11	48	4.36	12	10	39	3.9	5	12	4.1	Do.
Aug. 13.....	Okra bloom and bud.	9	72	8.0	11	9	44	4.9	12	12	6.4	Bred from squares and fed on blooms until Aug. 7.
Aug. 2.....	Okra fruit.....	10	75	7.5	17	10	75	7.5	14	17	7.5	Collected in field.
Aug. 13.....	do.....	8	60	7.5	15	8	55	6.9	12	15	7.2	Bred weevils.
Aug. 24-27.....	do.....	14	123	8.8	18	14	164	11.7	20	20	10.3	Field collected.
Sept. 9.....	do.....	12	131	10.9	39	12	155	12.9	20	39	11.9	Do.
July 28.....	Hibiscus leaves	7	36		(1)	(1)	(1)			5	5.1	Collected in field.
July 28.....	Hibiscus blooms	32	156							12	4.9	Not sexed. Not included in averages by sexes.
Aug. 25.....	Hibiscus buds.....	4	18							5	4.5	Do.
Aug. 18.....	Hibiscus bolls.....	40	185							9	4.6	Do.
Total on malvaceous plants other than cotton.....		70	531	7.6	39	69	559	8.1	20	39	6.7	

VARIETY GRANDIS WITH NORMAL FOOD.

May 15.....	Cotton leaves...	57	540	9.47	40	38	401	10.55	27	40	9.91	Hibernated.
June 12.....	do.....	40	269	6.73	17	40	259	6.25	15	17	6.60	Bred.
June 7.....	do.....	38	258	6.80	17	39	332	8.51	32	32	7.66	Do.
Aug. 9.....	do.....											
Sept. 17.....	do.....											
Total on cotton leaves.....		135	1,067	7.9	40	117	992	8.48	32	40	8.17	
June 3.....	Cotton terminals	28	468	16.70	43	28	627	22.40	42	43	19.55	Field collected; probably hibernated.
July 8.....	do.....	14	232	16.60	32	15	282	18.80	43	43	17.72	Bred.
Aug. 11.....	do.....	13	142	10.90	31	11	159	14.50	31	31	12.54	Do.
Sept. 7.....	do.....	20	259	13.00	31	19	187	9.84	45	45	11.44	Do.
Total on cotton terminals.....		75	1,101	14.68	43	73	1,255	17.19	45	45	15.92	
June 23.....	Cotton bolls.....	17	345	20.3	75	17	723	42.53	82	82	31.41	Do.
June 24.....	do.....											
June 20.....	Cotton squares..	11	729	66.27	83	13	762	58.62	81	83	62.13	Bred. First generation.
June 21.....	do.....											
July 16.....	do.....	5	197	39.40	57	5	167	33.30	59	59	36.40	Bred. Second generation.
Aug. 9.....	do.....											
Total on cotton squares.....		16	926	57.88	83	18	929	51.61	81	83	54.56	
Total all grandis on cotton.....		243	3,439	14.15	83	225	3,899	17.33	81	83	15.68	

TABLE II.—Duration of life of boll weevils. Observations of 1915—Continued.

VARIETY THURBERIAE.

Date.	Substance provided.	Males.				Females.				Both sexes.		Notes on weevils.
		Number.	Weevil days.	Average longevity.	Maximum longevity.	Number.	Weevil days.	Average longevity.	Maximum longevity.	Maximum longevity.	Average longevity.	
Aug. 30....	Okra fruit.....	8	163	<i>Days.</i> 20.4	<i>Dys</i> 39	8	129	<i>Days.</i> 16.1	<i>Dys</i> 37	<i>Dys</i> 39	<i>Days.</i> 18.3	Removed from bolls collected in Arizona Mar. 1, 1915.
May 3.....	Cotton leaves...	11	647	58.82	97	10	616	61.6	78	97	60.14	
July 15.....	do.....	5	350	70.0	78	.....	.....	.....	.....	.....	.....	Do.
July 18.....	First generation on squares.	16	1,136	71.0	104	19	1,269	66.8	89	104	68.7	Do.
Sept. 29.....		6	250	41.7	61	10	478	47.8	66	66	45.5	Do.
July 17.....	Second generation on squares	6	250	41.7	61	10	478	47.8	66	66	45.5	Do.
Sept. 22.....		10	531	53.1	73	9	392	43.6	73	73	48.6	Do.
July 27.....	On cotton bolls..	10	531	53.1	73	9	392	43.6	73	73	48.6	Do.
Sept. 29.....		10	531	53.1	73	9	392	43.6	73	73	48.6	Do.
Total all <i>thurberiae</i> on cotton.....		48	2,914	60.71	104	48	2,755	57.40	89	104	59.05	

¹ Weevils not sexed.

The *grandis* males averaged 3.24 days with no food; 7.6 days on okra and Hibiscus; 7.9 days on cotton leaves; 14.68 days on cotton terminals; 20.3 days on cotton bolls, and 57.88 days on cotton squares. The average longevity of male *grandis* on parts of the cotton plant was 14.15 days.

The *thurberiae* males averaged 20.4 days on okra fruit; 62.3 days on cotton leaves, 53.1 days on cotton bolls, and 63 days on cotton squares. The average longevity of *thurberiae* males on parts of the cotton plant was 60.71 days.

The *grandis* females averaged 3.88 days with no food; 8.1 days on okra and Hibiscus; 8.48 days on cotton leaves; 17.19 days on cotton terminals; 42.53 days on cotton bolls, and 51.61 days on cotton squares. The average longevity of female *grandis* on parts of the cotton plants was 17.33 days.

The *thurberiae* females averaged 16.1 days on okra fruit; 61.6 days on cotton leaves; 43.6 days on cotton bolls, and 60.2 days on cotton squares. The average of female *thurberiae* on parts of the cotton plant was 57.4 days.

A comparison of the longevity of the two varieties on okra fruit, cotton leaves, cotton bolls, and cotton squares is shown in Table III.

TABLE III.—Comparative longevity of *Anthonomus grandis* and *A. g. thurberiae*.

Food.	Average longevity of <i>grandis</i> .	Average longevity of <i>thurberiae</i> .
	<i>Days.</i>	<i>Days.</i>
Okra fruit.....	5.4	18.3
Cotton leaves.....	8.17	62.04
Cotton bolls.....	31.41	48.6
Cotton squares.....	54.56	61.4
Average longevity irrespective of food.....	14.13	53.2

The longevity of *thurberiae* is greater in every instance than that of *grandis*, and the average longevity irrespective of food is nearly forty days greater for the *thurberiae* weevils.

The maximum longevity obtained in the 1915 experiments is 104 days, this record being made by a male *thurberiae* feeding on cotton squares.

The maximum longevity with no food was 40 days; on okra and Hibiscus 39 days; on cotton leaves 97 days; on cotton bolls 82 days; on cotton terminals 45 days, and on cotton squares 104 days.

The comparison of the longevity by sexes is shown in Table IV. Here it is seen that in *grandis* the females exceeded the males on every food except cotton squares while in the *thurberiae* variety the males lived the longer in each case. The observations relating to *grandis* are in accord with the earlier records, which stated that the females exhibited greater hardihood on abnormal foods, but that the relation was reversed with normal food.

TABLE IV.—Comparison of longevity of the boll weevil by sexes. Observations of 1915.

VARIETY GRANDIS.

Food.	Males.			Females.		
	Number.	Weevil days.	Longevity.	Number.	Weevil days.	Longevity.
			<i>Days.</i>			<i>Days.</i>
None.....	136	440	3.24	91	353	3.88
Malvaceous plants.....	70	531	7.60	69	559	8.10
Cotton leaves.....	135	1,067	7.90	117	992	8.48
Cotton terminals.....	75	1,101	14.68	73	1,255	17.19
Cotton bolls.....	17	345	20.30	17	723	42.53
Cotton squares.....	16	926	57.88	18	929	51.61
Total <i>grandis</i>	449	4,410	9.82	385	4,811	12.50

VARIETY THURBERIAE.

Okra.....	8	163	20.4	8	129	16.1
Cotton leaves.....	16	997	62.3	10	616	61.6
Cotton bolls.....	10	531	53.1	9	392	43.6
Cotton squares.....	22	1,386	63.0	29	1,747	60.2
Total <i>thurberiae</i>	56	3,077	54.9	56	2,884	51.5

The longevity records of 1914 and 1915 added to those previously obtained show that 6,119 weevils fed on water averaged 9.9 days; 308 weevils fed on cotton averaged 8.6 days; 542 weevils fed on malvaceous plants averaged 9 days; 146 weevils fed on cotton foliage averaged 24.3 days and 534 weevils fed on cotton squares averaged 54.2 days. The most interesting features of the recent investigations on longevity are the greater adaptability of *grandis* for abnormal food plants and the very great longevity of *thurberiae* on any food. In view of this trend displayed by *grandis* and the adaptations which have already been made by *thurberiae* it seems reasonable to expect that *grandis* will continue to acquire greater hardihood when offered only abnormal foods.

Field cage studies.—For comparison with the laboratory tests of longevity, several experiments were conducted in field cages. Large cages covered with 16-mesh screen were placed over growing cotton plants and the first hibernated weevils found in the field in the spring were placed in them. Six cages in all were started on dates ranging from May 12 to June 19. These cages were watched for the cessation of weevil injury to the plants. However, the greater part of the new weevils died almost immediately after installation and the latest date on which a weevil was observed alive was July 22. It is apparent that the conditions are very abnormal in these cages, owing to the effect upon the light, temperature, humidity, etc. In fact, the plants themselves make a very abnormal growth when caged. A few observations were made during this period to determine the difference in temperature inside and outside these cages and they indicated a slightly higher daily maximum inside the cage than outside. The observations generally indicate that the conditions are very abnormal in these cages and that there is serious danger of error in drawing conclusions based only on such observations.

FOOD PLANTS OF THE WEEVIL.

During the early investigations on the boll weevil many attempts were made to find the weevils feeding or breeding on any plant other than cotton but they were uniformly unsuccessful. In fact, the first record of a cotton boll weevil feeding in nature on any plant other than cotton was in 1913, when one individual was found at Victoria, Tex., eating a bloom of *Hibiscus syriacus*. Observations since that time have shown a number of cases of the weevils feeding on plants closely related to cotton. The most important of these seem to be okra and the various wild species of *Hibiscus*.

Okra.—Okra is found very closely associated with cotton in many parts of the cotton belt. In fact, the plants are usually scattered through the cotton fields or are in the small garden patches adjoining cotton. Consequently there is a very good opportunity for the weevils to attack this plant.

During 1915 a number of okra plants were examined for weevils with the following results: On September 10 a few plants were examined at Inverness, Miss. Three open blooms were found and five boll weevils were in them, one blossom containing three. On September 29 and 30 a total of 122 okra plants were examined between Tallulah and Mound, La. These plants had 114 open blooms but the only weevil found was on the fruit. This individual was watched for about five minutes and in this time it made no attempt to feed.

Several additional records of the weevil on okra were made during the season on the plants growing at the laboratory and also in the field. Nearly all of these weevils were in the blooms and, where feeding was found, it was confined to the petals and stamens. No evidence of breeding in the buds or fruit in nature was secured.

Laboratory studies were also made upon the feeding in captivity and the possibility of breeding in the buds or fruit of okra. Sixty-nine pairs of weevils were mated on okra buds and small fruit and given only this food until death. Eleven eggs were deposited normally and three externally, but the larvæ failed to survive on this food. The weevils fed quite freely on these foods and also on okra blooms. In fact, the greatest amount of feeding was on the immature boll at the base of the bloom. Occasionally this small boll would be riddled with feeding punctures.

One cage test was conducted in the attempt to produce somewhat the conditions which would exist if cotton planting were suddenly stopped and only okra left for food. For this purpose a large cage was erected in the laboratory yard over a row of growing cotton plants and a row of okra (fig. 2). On August 27, 100 weevils, 50 males and 50 females, collected from cotton in the field were placed in the cage. Daily observations on the relative number of weevils on cotton and okra were made for 10 days. During this time 294 observations were made of weevils on cotton, while they were found on the okra only 16 times.

On September 6 the cotton plants were carefully removed from the cage and only the growing okra left for the weevils. On September 7 six weevils were feeding on the okra and on September 8 seven weevils were located, one feeding on a leaf and three feeding on the bloom. On September 9 three examinations were made and from 3 to 6 weevils, one of which was feeding on a bloom, were found on the okra each time. After that date the weevils were found on the okra only at irregular intervals and on September 19 no live weevils were found in the cage. At this time all the okra fruit was closely examined for egg punctures but none were found. However, to make sure that none were overlooked, all the fruit was placed on moist sand in a breeding cage and saved for some time, after which the contents were examined but no signs of larval work were found.

Hibiscus.—Two species of *Hibiscus* are found commonly around Tallulah, La., viz, *militaris* and *moscheutos*. One plant of *Hibiscus lasiocarpus* was found but does not seem to be common. *H. militaris* and *H. moscheutos* are found principally in low, moist places such as

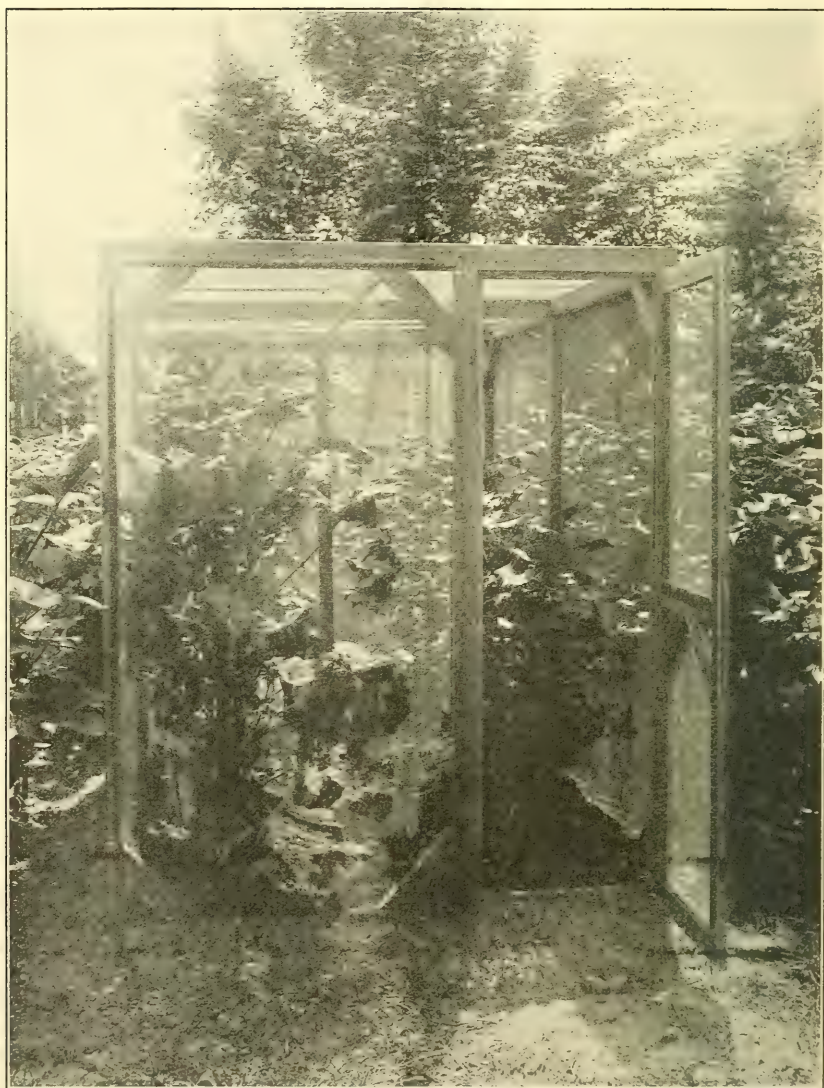


FIG. 2.—One of the cages containing cotton and okra plants, Delta, La. Photographed at time of introduction of boll weevils. (Original.)

the bayou banks, in roadside ditches, and in swamp land, where they grow to considerable size and fruit throughout most of the summer. No weevils were found on these, but practically all of the plants noted were some distance from cotton.

One plant of *H. militaris* was transplanted to the laboratory yard and a number of adult weevils were found feeding in the blooms during the season. The feeding was apparently confined to the stamens and petals.

In addition to these field observations laboratory studies were conducted in an attempt to rear weevils in Hibiscus buds as was done at Victoria, Tex., in 1913. In connection with these attempts, some interesting feeding records were secured.

Thirty-two weevils that were fed with Hibiscus blooms only were noted to feed freely on the petals, and four cases of feeding on the immature boll at the base of the bloom were also noted.

Four weevils were fed on Hibiscus buds alone; they fed sparingly but deposited no eggs.

In an experiment where 127 weevils were placed in breeding jars with fresh Hibiscus fruits, considerable feeding was noted and 5 eggs were deposited, 4 externally and 1 normally. The eggs deposited externally were placed in incisions in the Hibiscus bolls and saved on moist sand, but later examinations of these bolls showed no sign of larval work.

Other plants.—On September 4 two weevils were found on the foliage of cultivated zinnia growing at the laboratory.

Early in the spring hibernated weevils were confined in breeding cages with blooms of violet, peach, pear, and osage-orange and left until death, but no sign of feeding was found.

While the weevils were not found breeding on the various malvaceous plants and the laboratory attempt to get them to do so gave negative results, the increasing adaptability of the weevil to them as food is quite evident.

FEEDING HABITS ON COTTON LEAVES AND TERMINALS.

In connection with the studies on the longevity of the weevils on cotton leaves and terminals as already reported, a number of interesting observations were made on the character and extent of the feeding. Normally the weevils apparently never feed upon the leaves, and the feeding on the terminals is largely limited to the time before the first squares appear in the spring.

Cotton leaves.—Eighty pairs of weevils were placed in breeding cages on cotton leaves during the season and observations were made on a total of 747 weevil days. During this time the weevils fed 128 days on the leaf tissue alone, 30 days on the stem alone, and 211 days on both stem and leaf tissue; in other words, 34.7 per cent of the feeding was on leaf tissue, 8.1 per cent on stem, and 57.2 per cent on both leaf and stem. The feeding of *grandis* on the leaf tissue usually consisted of a limited number of small punctures but that of *thurberiae* was much more voracious. The latter would frequently devour almost the entire leaf in a day.

Cotton terminals.—Seventy-five pairs of weevils were fed on cotton terminals during the season and observations were made on a total of 1,920 weevil days. Feeding was observed on 1,226 weevil days. On 616 days the weevils fed on the stem alone, or 50.2 per cent of all feeding was on this part. On 602 days, or 49.1 per cent of the feeding days, the feeding was on both the stem and bud, while the bud alone was attacked on only 8 days, or 0.7 per cent of the feeding days.

The preference of the weevil for the stem in these two series was quite marked. This may be due to the mechanical stimulus presented by the shape of the stem which will allow punctures more or less like those made in the squares and bolls.

TABLE V.—*Relative proportions of the sexes of boll weevils. Observations of 1915.*

Variety and description of material.	Male.		Female.	
	Number.	Per cent.	Number.	Per cent.
<i>Grandis</i> :				
Hibernated weevils.....	439	55.00	360	45.00
Bred weevils.....	1,591	51.59	1,493	48.41
Total <i>grandis</i>	2,030	52.28	1,853	47.72
<i>Thurberiae</i> :				
Bred from cotton squares.....	71	55.98	56	44.02
Bred from cotton bolls.....	4	40.00	6	60.00
Total <i>thurberiae</i>	75	54.74	62	45.26
Hybrids:				
Male <i>thurberiae</i> and female <i>grandis</i>	52	50.49	51	49.51
Male <i>grandis</i> and female <i>thurberiae</i>	50	44.25	63	55.75
Total hybrids.....	102	47.22	114	52.78
Total and average of all weevils.....	2,207	52.10	2,029	47.90

• SEX OF ADULTS.

A considerable number of the weevils handled during the season were sexed, and Table V shows the ratio of the sexes.

Of the hibernated *grandis* material, 439 were males and 360 were females, or 55 per cent males and 45 per cent females. Of the *thurberiae* weevils extracted from *Thurberia* bolls, 54.74 per cent were males and 45.26 per cent were females. Of the 214 sexed hybrid weevils bred during the season 47.22 per cent were males and 52.78 per cent were females. These last figures are in accordance with the observations in 1913 that there was a larger percentage of females in variety *thurberiae* and the hybrids than in the variety *grandis*.

PERIOD FROM EMERGENCE TO OVIPOSITION.

In the series of typical *grandis* females the period from emergence to oviposition when fed on squares varied from 2 to 16 days with an average of 6.6 days. Fourteen females emerging in late June averaged 5.9 days from emergence to oviposition and 5 females emerging in late July and early August averaged 8.8 days from emergence to oviposition. Thus it is shown that temperature has a

direct influence on the length of time elapsing between emergence and oviposition. Ten typical *thurberiae* emerging in late July and early August averaged 6.8 days from emergence to oviposition. These periods ranged from 3 to 10 days. *Grandis* females in Texas in 1913 averaged 6.1 days and *thurberiae* females 4 days. At Tallulah in 1910, 34 females averaged 6.35 days before oviposition.

PERIOD FROM FIRST FEEDING ON SQUARES TO OVIPOSITION.

The period from first feeding on squares after emergence from hibernation to egg deposition was observed only with typical *thurberiae* females and with crosses of *grandis* and *thurberiae*. With typical *thurberiae* emerging in June it ranged from 10 to 18 days with an average of 13.3 days, while male *thurberiae* mated with female *grandis* varied from 3 to 10 days with an average of 7 days. With female *thurberiae* mated with male *grandis* the period varied from 9 to 18 days with an average of 12 days. Female *thurberiae* mated with male *grandis* in Texas in 1913 averaged 13.5 days in May and June and 3 days in early September, while hibernated *grandis* males averaged 4.2 days in early May. These records seem to indicate that the period is several days longer for *thurberiae* than for *grandis*.

FECUNDITY.

In connection with the various breeding series conducted during 1915 a considerable amount of information on the fecundity of the females of various types was secured.

Fecundity of hibernated grandis females.—Questions have frequently been raised concerning whether or not it is necessary for a female to be fertilized in the fall to pass the winter safely and also as to whether or not it is necessary for the females to be fertilized in the spring before deposition can start. Two series of females were tested to determine their exact condition upon emergence from hibernation in the spring. One series consisted of isolated females which were collected immediately after emergence started and which were not offered an opportunity for copulation after that time, while in the other series males were left with the females throughout their life. Of course there is a possibility that some of these females may have been fertilized during the time between emergence and collection but this is very slight as the emergence had just started and they had had very little time in which to copulate. Earlier studies have shown that either square or boll food is necessary before the female can be successfully fertilized and there were extremely few squares present in the field before the time of collection of these weevils, consequently it seems safe to assume that at least the majority of these females had not been fertilized in the spring. Both series were given cotton squares for food and oviposition.

TABLE VI.—*Fecundity of hibernated females of Anthonomus grandis kept with males constantly during life.*

Activity of individual females.				Progeny produced by individual females.												Per cent- age eggs pro- duc- ing adults.			
Date female col- lected.	Date oviposi- tion began.	Date oviposi- tion ended.	Ovi- posi- tion pe- riod.	Eggs deposited.			Date male dead.	Date female dead.	Period last egg to death of female.	Male weevils bred.	Male weevil days.	Male devel- op- men- tal period.	Fe- male weev- ils bred.	Female devel- op- men- tal period.	Total wee- vil days.		Total both sexes.		
				Nor- mally.	Total.	Aver- age per day.													
May 26	June 3	Aug. 3	Days.	123	0	123	2.0	9	July 4	Aug. 3	0	121	Days.	176	Days	22	297	Days.	17.89
Do.	June 1	June 9	9	5	0	5	6	4	July 14	June 9	1	14	13.4	13	13.5	2	287	13.5	40.00
Do.	June 2	June 26	25	63	0	63	2.5	5	July 14	July 5	2	29	14.0	1	14	2	28	14	17.89
Do.	June 6	June 29	24	26	0	26	1.1	4	July 24	June 30	1	13	14.5	7	105	134	14.9	14.29	
Do.	June 1	July 5	35	40	0	40	1.1	6	July 16	July 9	3	48	13	1	13	2	26	13	7.69
Do.	June 2	June 28	23	41	0	41	1.8	4	July 7	July 2	4	14	16	2	32	5	80	16	12.50
Do.	June 3	June 18	17	19	0	19	1.1	3	July 31	June 22	4	0	.....	3	43	4	57	14	9.76
Do.	June 2	July 10	47	107	0	107	2.3	7	July 14	July 22	11	163	14.8	10	140	21	303	14.5	10.53
Do.	June 2	July 12	39	93	0	93	2.4	9	June 15	July 13	8	119	14.9	2	27	10	146	14.6	10.75
Do.	June 22	July 12	21	1	1	1	1	6	June 8	July 24	17	17	17	0	0	1	17	17	50.00
Do.	June 25	July 31	34	108	0	108	3.2	6	July 17	July 10	5	71	14.2	6	83	11	154	14	10.19
Do.	June 4	July 31	58	98	0	98	1.7	7	July 26	Aug. 2	2	72	14.4	12	168	17	240	14.1	17.35
Do.	June 2	June 23	22	19	0	19	1.9	3	June 31	June 28	5	44	14.7	1	44	4	56	14	21.05
Do.	June 17	July 31	45	105	0	105	2.3	7	Sept. 3	Aug. 6	3	78	15.6	3	39	8	122	15.25	7.62
Do.	June 20	Aug. 23	65	32	4	36	6	5	Sept. 5	Sept. 5	13	69	13.8	3	39	10	108	13.5	22.22
Do.	June 18	July 18	31	73	0	73	2.4	7	July 6	July 24	6	81	13.5	4	56	13	137	13.7	13.70
Do.	June 18	July 14	27	150	1	151	5.6	12	Aug. 31	July 17	3	119	14.9	3	39	11	158	14.4	7.28
Do.	June 20	June 26	1	1	1	1	1	8	June 27	June 21	1	.....	.....	.....	.....	.....	.....	.....	0
Do.	June 18	Aug. 4	48	128	1	129	2.7	8	Aug. 27	Aug. 8	10	132	13.2	12	155	22	287	13	17.05
Do.	June 19	Aug. 5	48	156	1	157	3.3	7	June 30	Aug. 9	13	179	13.8	20	268	33	447	13.5	21.02
Total.....			681	1,388	9	1,397	2.65	115			97	1,383		105	1,443	202	2,826		
Average.....			31.5	69.4	.45	69.85	5.75	5.75			13	14.3		20	13.7	33	17.0	14.0	14.46
Maximum.....			65	156	4	157	5.6	12			13	17.0		20	16.0	33	17.0	17.0	50.0
Minimum.....			1	1	2	2	.6	.....			.....	13.0		0	12.0	0	.....	13.0	.....

1 Escaped.

Latest date of deposition, August 23. Average date of cessation of oviposition, July 13.

TABLE VII.—*Fecundity of hibernated females of Anthonomus grandis not fertilized in spring.*

Activity of individual females.					Progeny produced by individual females.																
Date female collected.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.					Period last egg to death of female.	Progeny produced by individual females.											
				Externally.	Normally.	Total.	Average per day.	Maximum per day.		Date female dead.	Male weevils bred.	Male weevil days.	Male development period.	Female weevil days.	Female development period.	Total weevils bred.	Period both sexes.	Percentage eggs producing adults.			
June 1	June 2	June 29	28	32	0	32	1.2	3	June 30	Days.	6	87	14.5	3	41	13.7	9	128	14.2	28.13	
Do.	do.	July 10	39	26	1	27	.7	4	July 14	4	2	28	14	0	0	0	2	28	14	7.40	
Do.	June 7	Aug. 22	77	49	9	58	.8	5	Aug. 23	1	5	69	13.8	6	81	13.5	11	150	13.6	18.96	
Do.	June 9	July 19	41	114	0	114	2.8	6	July 21	2	8	107	13.4	11	150	13.6	19	284	15.0	16.67	
Do.	June 16	July 21	36	14	1	15	.4	2	July 22	1	0	0	0	1	12	12	1	12	12	6.67	
Do.	June 20	June 28	20	2	2	4	.2	2	June 30	0	0	0	0	1	17	17	1	17	17	25.00	
Do.	June 12	July 8	27	4	4	8	.3	2	July 14	10	1	11	11	0	0	0	1	11	11	5.56	
Do.	June 9	July 19	41	10	8	18	.4	3	July 23	13	1	14	14	0	0	0	1	14	14	7.69	
Do.	June 7	June 30	24	8	5	13	.5	2	July 13	1	1	16	16	1	16	16	2	32	16	11.76	
Do.	June 7	Aug. 4	59	6	11	17	.3	2	Aug. 5	1	1	16	16	1	16	16	2	32	16	11.76	
Do.	June 9	July 4	26	14	0	14	.5	3	July 15	11	1	15	15	2	29	14.5	3	44	14.7	21.43	
Do.	June 15	July 30	46	4	2	6	.1	2	Aug. 5	6	1	17	17	2	27	13.5	3	44	13.7	7.69	
Do.	June 17	Aug. 17	64	9	30	39	.6	3	Aug. 26	9	8	116	14.5	14	184	13.1	22	300	13.6	13.05	
Do.	June 11	July 15	35	127	2	129	3.1	7	July 17	2	5	66	13.2	3	43	14.3	8	109	13.6	20.00	
June 2	June 11	July 15	49	12	9	21	.4	4	Aug. 22	9	1	17	17	2	27	13.5	3	44	13.7	7.69	
Do.	June 26	Aug. 13	49	12	9	21	.4	4	Aug. 22	9	1	17	17	2	27	13.5	3	44	13.7	7.69	
Do.	June 19	July 3	15	1	2	3	.2	2	July 12	9	2	16	16	1	16	16	4	56	14.0	8.51	
Do.	June 10	Aug. 23	75	31	16	47	.6	5	Aug. 25	2	3	40	13.3	1	16	16	4	56	14.0	8.51	
Do.	June 14	July 17	34	54	0	54	1.6	6	July 20	3	6	78	13	3	39	13	6	117	13.0	16.67	
Do.	June 9	June 26	18	35	1	36	2.0	5	June 26	0	3	48	16	3	42	14	9	90	15	16.67	
Do.	June 10	Aug. 20	72	85	13	98	1.4	6	Aug. 25	5	13	78	13	9	129	14.3	15	207	13.8	15.31	
Do.	June 15	July 22	38	59	6	65	1.7	5	July 31	7	13	179	13.8	10	134	13.4	23	303	13.2	35.38	
Do.	June 10	July 24	45	72	2	74	1.6	5	July 31	7	8	111	13.9	7	96	13.7	15	207	13.8	20.27	
Do.	June 12	July 3	22	43	0	43	2.0	3	July 9	4	5	73	14.6	2	28	14.7	7	101	14.4	16.28	
Do.	June 10	July 7	28	57	0	57	2.0	3	July 11	6	8	111	13.9	8	109	13.6	16	220	13.75	28.07	
Total	1,000	907	1,032	125	125	1,032	1.03	92	92	122	91	1,264	13.9	87	1,193	13.7	178	2,457	13.8	17.25	
Average	40	36.28	41.28	5	5	41.28	3.1	3.68	7	5.3	13	7	11.0	14	17.0	13.7	23	17.0	13.8	17.25	
Maximum	77	127	129	30	30	129	3.1	7	11	13	13	170	11.0	14	17.0	12.0	23	17.0	13.8	35.38	
Minimum	15	1	3	0	0	3	.1	1	1	0	0	0	0	0	0	0	0	0	11.0	11.0	35.38

1 Escaped.

Latest date of deposition, August 23. Average date of cessation of oviposition, July 20.

From the results of these two series, shown in Tables VI and VII, it develops that all of the 25 isolated females deposited eggs, although 4 of them deposited less than 10 eggs each, whereas of the 20 fertilized females only 3 individuals deposited less than 10 eggs. The average oviposition period was 34.5 days for the isolated females and 40 days for females with the males. The average eggs for the isolated females was 41.2 with a maximum of 129, while for the females with males the average was 69.8 with a maximum of 157. However, it is seen that the isolated females averaged 5 eggs deposited externally while the females with males averaged only 0.45. Earlier studies have shown that practically all eggs deposited externally are infertile, which would indicate a lack of fertility on the part of isolated females. The average eggs per day for the isolated females ranged from 0.1 to 3.1 with a general average of 1.03, whereas for the females with males it ranged from 0.6 to 5.6 with an average of 2.05 eggs, thus proving the greater fecundity of the females with males.

The latest date of cessation of oviposition, August 23, was the same in both series, but the average date for the isolated females was 7 days later than that of the females with males. All eggs secured in both series were retained and as many adults as possible were reared. It is seen that 17.25 per cent of the eggs from the isolated females produced adults, while 14.46 per cent of those from the females with males produced adults. However, the eggs from every female in the series with males produced some adults, while those from 4 females in the isolated series failed to produce any.

From these observations it seems quite evident that at least a very high percentage of the females emerging in the spring are more or less fertile, but that their fecundity is considerably increased by later copulations.

Fecundity of first-generation grandis females.—The weevils used in this series were the first weevils bred during the season of 1915, the earliest emerging June 20. Thirteen pairs were mated and placed with cotton squares. (Table VIII.)

TABLE VIII.—*Fecundity of first-generation females of Anthonomus grandis on cotton squares.*

Date female emerged.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
June 20.....	June 26	Sept. 7	<i>Days.</i> 74	198	2.5	8
Do.....	do.....	Aug. 4	40	197	4.93	10
Do.....	June 29	Aug. 29	62	91	1.5	7
Do.....	June 28	July 28	31	57	1.8	5
June 21.....	June 26	July 20	25	89	3.7	9
Do.....	do.....	July 14	19	66	3.5	11
Do.....	June 23	Aug. 15	54	191	3.5	8
Do.....	June 27	Aug. 25	66	160	2.4	8
Do.....	do.....	Aug. 27	62	142	2.3	12
Do.....	June 28	Aug. 31	65	107	1.6	6
Do.....	June 26	Aug. 26	62	111	1.8	6
Do.....	do.....	July 28	33	110	3.3	7
Do.....	do.....	Aug. 23	59	204	3.5	10
Total.....			650	1,723		
Average.....			50	132.5	2.7	
Maximum.....			74	204	4.9	12
Minimum.....			19	57	1.5	5

The total number of eggs deposited by each female ranged from 57 to 204 with an average of 132.5. The average number of eggs per female per day was 2.7 and the maximum was 12. The oviposition period varied from 19 to 74 days with an average of 50 days.

Fecundity of second generation grandis females.—Five pairs of weevils emerging from the first generation series were mated and placed with cotton squares during the last of July and the first of August (Table IX.)

TABLE IX.—*Fecundity of second-generation females of Anthonomus grandis on cotton squares.*

Date female emerged.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
July 16.....	July 23	July 29	<i>Days.</i> 7	13	1.9	4
Aug. 13.....	Aug. 18	Sept. 4	18	42	2.3	6
July 16.....	July 27	do.....	40	93	2.3	8
July 29.....	Aug. 2	Sept. 5	35	175	5.0	10
Aug. 9.....	Aug. 17	Aug. 28	13	24	1.6	6
Total.....			113	347		
Average.....			22.6	69.4	3.1	
Maximum.....			40	175	5.0	10
Minimum.....			7	13	1.6	4

The total number of eggs per female ranged from 13 to 175 with an average of 69.4. The number of eggs per female per day varied from 1.6 to 5.0 and the maximum number was 10. The oviposition period ranged from 7 to 40 days with an average of 22.6 days.

Fecundity of hibernated thurberiae females.—The weevils used in this series were hibernated individuals extracted from cells in *Thurberia* bolls collected in Arizona on March 1, 1915. Nineteen pairs were mated on cotton squares on June 18. (Table X.)

TABLE X.—*Fecundity of hibernated females of Anthonomus grandis thurberiae on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
June 18.....	June 29	Aug. 8	<i>Days.</i> 41	46	1.1	4
Do.....	June 28	Aug. 2	36	82	2.3	6
Do.....	July 5	July 25	21	9	.4	3
Do.....	July 1	Aug. 7	38	109	2.9	7
Do.....	do.....	Sept. 4	66	90	1.4	4
Do.....	June 29	Aug. 16	49	49	1.0	4
Do.....	do.....	July 17	19	26	1.4	5
Do.....	June 28	Aug. 25	59	76	1.3	5
Do.....	July 3	Aug. 18	47	47	1.0	4
Do.....	do.....	July 29	27	54	2.0	4
Do.....	July 1	July 20	20	5	.25	2
Do.....	June 28	Sept. 9	74	58	.8	5
Do.....	July 1	Aug. 3	34	54	1.6	6
Do.....	July 2	Aug. 2	32	62	1.9	5
Do.....	July 1	Aug. 20	51	45	.9	5
Do.....	do.....	Aug. 27	58	57	1.0	5
Do.....	July 2	Aug. 14	54	69	1.3	6
Do.....	July 5	Aug. 2	29	73	2.5	6
Do.....	June 29	Aug. 6	39	57	1.5	4
Total.....			794	1,068		
Average.....			41.79	56.2	1.3	
Maximum.....			74.00	109	2.9	7
Minimum.....			19.00	5	.25	

The total eggs per female ranged from 5 to 109, with an average of 56.2. The average eggs per female per day was 1.3, while the maximum was 7. The oviposition period varied from 19 to 74 days, with an average of 41.79 days.

Fecundity of first-generation thurberiae females.—Ten pairs of the progeny of the hibernated *thurberiae* reared in cotton squares were mated on cotton squares. (Table XI.)

TABLE XI.—*Fecundity of first-generation females of Anthonomus grandis thurberiae on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
July 17.....	July 24	Sept. 1	<i>Days.</i> 40	72	1.8	5
July 18.....	July 28	Aug. 24	28	37	1.3	4
Do.....	July 24	Sept. 20	59	39	.7	5
Do.....	July 25	Sept. 9	47	15	.3	3
Do.....	July 25	Aug. 28	35	12	.3	3
Aug. 4.....	Aug. 10	Sept. 5	27	27	1.0	5
July 19.....	July 29	Sept. 22	25	11	.8	2
July 22.....	July 25	Aug. 3	10	7	.7	2
July 24.....	Aug. 3	Aug. 26	24	6	.3	2
Aug. 4.....	Aug. 7	Aug. 25	19	18	1.0	4
Total.....			314	244		
Average.....			31.4	24.4	1.4	
Maximum.....			59	72	1.8	5
Minimum.....			10	6	.3	

The number of eggs per female ranged from 6 to 72, with an average of 24.4, while the average per female per day was 1.4 and the maximum per day was 5. The oviposition period ranged from 10 to 59 days, with an average of 31.4 days.

From this and the preceding series the greatly reduced fecundity of *thurberiae* under the artificial condition prevailing at the Tallulah laboratory is quite evident.

Fecundity of bred grandis females mated with male thurberiae.—Late in June 12 newly emerged female *grandis* of the first generation were mated with hibernated male *thurberiae* on cotton squares. (Table XII.)

TABLE XII.—*Fecundity of bred females of Anthonomus grandis mated with male A. g. thurberiae on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			<i>Days.</i>			
June 22.....	June 29	July 7	9	35	3.9	7
July 27.....	Aug. 2	Sept. 8	38	134	3.5	9
June 22.....	July 2	July 28	27	124	4.6	8
July 27.....	Aug. 4	Aug. 31	28	19	.7	2
June 22.....	June 28	July 10	13	29	2.2	7
July 29 ¹	Aug. 1	Aug. 28	28	100	3.6	8
June 22.....	June 28	July 7	10	31	3.1	5
July 27.....	Aug. 5	Sept. 10	37	87	2.4	6
June 22.....	June 30	July 13	14	32	2.3	5
July 27.....	Aug. 3	Sept. 19	48	87	1.8	6
June 22.....	June 28	July 3	6	13	2.2	6
Do.....	July 1	Aug. 7	38	113	3.0	7
Dp.....	June 28	Aug. 10	44	166	3.8	15
Total.....			312	870		
Average.....			26	72.5	2.8	
Maximum.....			48	166	4.6	15
Minimum.....			6	13	.7	

¹ A complete record was not secured from this female owing to its escape on August 30, and consequently the figures are not included in the totals and averages.

The total eggs per female varied from 13 to 166, with an average of 72.5, and the average per female per day was 2.8. The oviposition period ranged from 6 to 48 days, with an average of 26 days.

The hybrid progeny reared from these eggs were mated on cotton squares and laid fertile eggs.

Fecundity of female thurberiae mated with male grandis.—In June 18 hibernated females of the variety *thurberiae* were mated with an equal number of male *grandis* on cotton squares. The detailed results are shown in Table XIII.

TABLE XIII.—*Fecundity of hibernated female Anthonomus grandis thurberiae mated with male A. grandis on cotton squares.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited.		
				Total.	Per day.	Maximum per day.
			<i>Days.</i>			
June 19.....	July 3	Sept. 7	67	31	0.5	3
Do.....	June 28	Sept. 3	68	77	1.1	4
Do.....	July 2	Aug. 13	43	133	3.1	8
Do.....	June 28	Aug. 6	40	48	1.2	5
Do.....	June 29	Sept. 2	66	72	1.1	4
Do.....	do.....	Aug. 3	36	65	1.8	5
Do.....	July 3	Aug. 4	33	47	1.4	4
Do.....	July 5	July 24	20	31	1.5	3
Do.....	June 30	Aug. 22	54	59	1.1	4
Do.....	July 7	Aug. 21	45	40	.9	4
Do.....	July 5	Aug. 20	47	51	1.1	4
Do.....	July 2	July 28	27	30	1.1	4
Do.....	June 28	Aug. 2	36	77	2.2	6
Do.....	do.....	Aug. 11	45	71	1.6	5
Do.....	July 1	Aug. 24	55	47	.9	5
Do.....	July 4	Aug. 4	32	32	1.0	2
Do.....	June 28	Aug. 2	36	35	1.0	4
Do.....	do.....	July 24	27	24	.9	4
Total.....			777	970		
Average.....			43.2	54	1.3	
Maximum.....			68	133	3.1	8
Minimum.....			20	24	.5	

The total eggs per female ranged from 24 to 133, with an average of 54, and the general average per day was 1.3 eggs. The oviposition period varied from 20 to 68 days and averaged 43.2 days.

The progeny of this cross were also mated and produced fertile eggs.

Fecundity of bred grandis females on cotton bolls.—Eighteen pairs of bred *grandis* weevils were placed with cotton bolls and furnished only this food until death. Seven of these females died without depositing a single egg. The activities of the remaining 11 are shown in Table XIV.

TABLE XIV.—*Fecundity of bred females of Anthonomus grandis on cotton bolls.*

Date installed.	Oviposition.			Total eggs.	Eggs per day.	
	Started.	Ended.	Period.		Average.	Maximum.
			<i>Days.</i>			
July 9.....	July 18	Aug. 3	17	5	0.3	1
Do.....	July 19	July 25	6	3	.5	2
Do.....	July 14	Sept. 7	45	17	.4	2
Do.....	July 28	Aug. 22	26	13	.5	2
Do.....	July 16	Sept. 5	52	17	.3	2
Do.....	July 12	Sept. 10	61	24	.4	3
July 16.....	July 23	Aug. 7	16	5	.3	3
July 24.....	Aug. 7	Aug. 17	11	2	.2	1
Do.....	Aug. 6	Sept. 16	42	5	.01	2
Do.....	July 30	Aug. 17	19	2	.01	1
Do.....	July 26	Sept. 16	22	8	.4	2
Total.....			317	101		
Average.....			29	9	.3	
Maximum.....			61	24	.5	3
Minimum.....			6	2	.01	

The total eggs per female varied from 2 to 24, with an average of only 9, and the average per day was only 0.3. The oviposition period ranged from 6 to 61 days, with an average of 29 days.

These results indicate the great difficulty with which oviposition is performed when only bolls are offered for food, but at least a large percentage of the eggs deposited were fertile, as 20 adults were reared from them.

Fecundity of hibernated thurberiae females on cotton bolls.—Nine pairs of *thurberiae* weevils were extracted from their hibernation cells in *Thurberia* bolls on July 27 and placed with cotton bolls at once. They were offered only this food until death. The results are given in Table XV.

TABLE XV.—*Fecundity of hibernated Anthonomus grandis thurberiae on cotton bolls.*

Date installed.	Date oviposition began.	Date oviposition ended.	Oviposition period.	Eggs deposited—			Maximum per day.
				Normally.	Externally.	Total.	
			<i>Days.</i>				
July 27.....	Aug. 11	Sept. 18	39	1	62	63	7
Do.....	July 28	Sept. 5	41	1	1	2	1
Do.....	Aug. 15	Aug. 28	14	1	1	2	1
Do. ¹	July 28	Aug. 20	24	6	8	14	3
July 27.....	Aug. 4	Aug. 18	15	2	5	7	2
Do.....	July 28	Sept. 24	59	1	2	3	.....
Do.....	Aug. 4	Aug. 16	13	4	1	5	2
Do.....	Aug. 18	Sept. 9	23	1	1	2	1
Do.....	July 30	July 30	1	.....	1	1	1
Total.....			204	11	74	85	.....
Average.....			25.5	1.3	9.3	10.6	.....
Maximum.....			59	4	62	63	7
Minimum.....			1	.....	1	1	.....

¹ This female escaped Aug. 20, and consequently is not included in the averages.

One of these females escaped, and consequently only eight are considered in the averages. These eight deposited a total of only 85 eggs, and 74, or 89.4 per cent of these were deposited externally. It is striking that every female that deposited any eggs laid one or more externally. This is positive evidence of the unsuitability of bolls as food for these weevils.

The average total eggs per female was 10.6 and the average number deposited normally was only 1.3. These eggs were fertile, however, as several adults were reared from them.

Fecundity of grandis females on cotton bolls and squares on alternate days.—In addition to the foregoing studies on the effect of cotton bolls on the deposition of females another series was conducted in which each female was offered squares and bolls on alternate days. These females were bred individuals, which were fed squares until normal deposition started. Consequently this series does not show the effect of the boll food upon the fecundity of the females, but

simply shows the relative effect of the bolls and squares upon the act of oviposition. Table XVI shows the activity of nine females treated in this manner.

TABLE XVI.—*Fecundity of females of Anthonomus grandis on cotton squares and cotton bolls on alternate days.*

Eggs deposited in squares.			Eggs deposited in bolls.		
Total.	Maximum per day.	Average per day.	Total.	Maximum per day.	Average per day.
10	2	0.36	16	2	0.58
21	8	1.28	6	2	.12
24	6	2.00	5	1	.50
21	9	5.26	6	3	1.50
5	3	.28	8	3	.46
40	11	2.42	19	3	1.16
25	7	1.36	16	5	.86
23	5	1.54	11	2	.74
4	3	.16	1	1	.12
37	11	1.42	21	4	.80
41	9	1.52	12	3	.68
251	11	1.21	121	5	.59

From this it is seen that the average eggs per female per day was 1.21 on cotton squares and 0.59 on bolls. Consequently the greater suitability of the square for deposition is quite evident.

Summary of all fecundity observations on cotton squares.—Table XVII gives a brief summary of the foregoing studies on fecundity when the females were with males throughout life and were fed cotton squares. Here it is seen that the three series containing *thurberiae* females gave the lowest average of total eggs per female, and that the first-generation *grandis* gave the highest. The average eggs per female in all series was 68.2 and the average per day was 1.8.

TABLE XVII.—*Fecundity of all boll weevils on cotton squares: Summary.*

Source.	Number females.	Average eggs per female.	Average oviposition period.	Eggs per day.	
				Average.	Maximum.
Hibernated <i>grandis</i>	20	69.85	<i>Days.</i> 34.5	2.1	12
First generation <i>grandis</i>	13	132.54	50	2.7	12
Second generation <i>grandis</i>	5	69.4	22.6	3.1	10
Hibernated <i>thurberiae</i>	19	56.2	41.79	1.3	7
First generation <i>thurberiae</i>	10	24.4	31.4	3.5	5
Female <i>grandis</i> and male <i>thurberiae</i>	12	72.5	26	2.8	15
Female <i>thurberiae</i> and male <i>grandis</i>	18	54	43.2	1.3	8
Total.....	97				
Average.....		68.2	37.7	1.8	

The averages are all surprisingly low, the lowest on record for a season for the boll weevil, in fact. In 1902 to 1904, at Victoria, Tex., the females averaged 89 eggs each at the rate of 2.8 per day, while at

the same place in 1913 they averaged 212 eggs each at the rate of 5.9 per day. That this year's low record is not due to the difference in localities is shown by the fact that at Tallulah in 1910 the weevils averaged 208 eggs per female, at the rate of 5.5 eggs per day. The low records of 1915 may have been due to the extremely hot, dry weather prevailing during the period when most of the observations were made.

OVIPOSITION PERIOD.

The oviposition period of 122 females was observed during 1915. The results are shown in Table XVIII.

TABLE XVIII.—*Oviposition period of the boll weevil on cotton squares.*

Source of weevils.	Season.	Number of females.	Period.		
			Maximum.	Minimum.	Average.
Hibernated <i>grandis</i>	May-June.....	20	65	1	34.5
Hibernated <i>grandis</i> unfertilized in spring.....	June-August.....	25	77	15	40.0
First generation <i>grandis</i>	June-September.....	13	74	19	50.0
Second generation <i>grandis</i>	do.....	5	40	7	22.6
Hibernated <i>thurberiae</i>	do.....	19	74	19	41.79
First generation <i>thurberiae</i>	July-September.....	10	59	10	31.4
Male <i>thurberiae</i> and female <i>grandis</i>	June-September.....	12	48	6	26.0
Male <i>grandis</i> and female <i>thurberiae</i>	do.....	18	68	20	44.3
Total.....	May-September.....	122	-----	-----	-----
Weighted average.....					38.2
Maximum.....			77	-----	-----
Minimum.....				1	-----

The table shows that the oviposition period ranged from 1 to 77 days, with an average of 38.2 days for all females. The first generation *grandis* had the longest average period and the second generation *grandis* the lowest. There is no great difference between the length of the oviposition periods of *grandis* and *thurberiae*.

A series of 8 *thurberiae* females on cotton bolls averaged 25.5 days, with a maximum of 59 days and a minimum of 1 day, while a series of 11 *grandis* females on cotton bolls averaged 29 days, with a maximum of 61 days and a minimum of 6 days.

Observations of 32 females on cotton squares at Tallulah in 1914 showed an average oviposition period of 34.4 days, a maximum period of 80 days and a minimum period of 10 days. The average oviposition at Tallulah in 1910 was 34.44 days, and the average period in Texas in 1913 was 35.8 days. All records of female oviposition periods average several days less than the 1915 record of 38.2 days at Tallulah. Thus it is seen that if there is any tendency toward a change in the length of the oviposition period of the weevil it is in the nature of an increase rather than a decrease.

RATE OF OVIPOSITION.

The rate of oviposition by thirds of the period is shown in Table XIX. From this it is seen that the general average eggs per female per day was the same in the first and second thirds, while in the last it was lower.

TABLE XIX.—Rate of oviposition of the boll weevil obtained in all experiments.¹

Nature of weevils.	Number of females.	Season.	Rate of oviposition.					
			First third of period.		Second third of period.		Last third of period.	
			Total eggs.	Daily avg.	Total eggs.	Daily avg.	Total eggs.	Daily avg.
Hibernated <i>grandis</i>	19	May to Aug...	505	2.3	504	2.2	387	1.7
First generation <i>grandis</i>	13	June to Sept...	578	2.7	692	3.2	453	2.0
Second generation <i>grandis</i>	5	July to Sept...	152	4.2	122	3.3	77	1.9
First generation <i>thurberiae</i>	10	...do.....	133	1.3	65	.6	46	.4
Hibernated <i>thurberiae</i>	19	June to Sept...	407	1.6	379	1.4	282	1.0
Male <i>grandis</i> and female <i>thurberiae</i> ...	18	...do.....	397	1.5	373	1.4	198	.8
Male <i>thurberiae</i> and female <i>grandis</i> ...	13	...do.....	289	2.7	392	3.5	275	2.3
Total.....			2,461		2,527		1,718	
Average.....				2.1		2.1		1.4

¹ Owing to the fact that the oviposition periods were rarely exactly divisible by 3 it was frequently necessary to allow a difference of a day on one or more of the periods. For this reason the divisors used in computing the final average were slightly different, and consequently the same average per day was secured in the first and second period, though the total eggs were slightly higher in the second period.

MAXIMUM NUMBER OF EGGS PER DAY.

The maximum number of eggs deposited by a female in a day was 15, this number being deposited on July 17 by a *grandis* female fertilized by a *thurberiae* male. This maximum is much lower than the maxima of previous years. The maxima of the various series carried through this year varied from 5 to 15 eggs.

The record for maximum eggs per day was made at Tallulah in 1914 when a first generation female laid 27 eggs. The maximum number of eggs in a day before this time was 26, this record being made by a female at Victoria, Tex., in 1913.

PERIOD FROM DEPOSITION OF LAST EGG TO DEATH.

The number of days from the deposition of the last egg to the death of the female varied from 54 days to death on the same day as the last deposition. The average of the 120 weevils observed during the season was 5.8 days. Typical *grandis* averaged 4.4 days to death, the periods of the individuals varying from none to 13 days. Typical *thurberiae* averaged 9.7 days, the periods varying from none to 54. Female *grandis* mated with male *thurberiae* averaged 2.3 days, the periods varying from none to six, while female *thurberiae* mated with male *grandis* averaged 6.2 days, the period varying from none to 24 days.

This period in the 1914 studies varied from 22 days to death on the same day that the last egg was deposited, with an average of 3.4 days. Death on the last day of deposition was observed five times during the season.

ACTIVITY OF FEMALES IN DIFFERENT PARTS OF THE DAY.

Early in August, 1914, two tests were conducted to determine the egg-laying activity of the females during the different parts of the day. Nine actively depositing females were used in each test. The results are shown in Table XX.

TABLE XX.—*Periodic division of oviposition of boll weevils.*

FIRST TEST: AUGUST 4 AND 5.

Period.	Length of period.	Total eggs laid.	Percentage of total oviposition in each period.	Maximum temperature.
			<i>Per cent.</i>	<i>° F.</i>
Dawn.....	5 a. m. to 9 a. m..	16	12.8	77
Morning.....	9 a. m. to 1 p. m..	47	37.6	86
Afternoon.....	1 p. m. to 5 p. m..	29	23.2	90
Evening.....	5 p. m. to 8 p. m..	23	18.4	85
Night.....	8 p. m. to 5 a. m..	10	8.0	75

SECOND TEST: AUGUST 7 AND 8.

Dawn.....	5 a. m. to 9 a. m..	8	9.1	72
Morning.....	9 a. m. to 1 p. m..	27	30.7	81
Afternoon.....	1 p. m. to 5 p. m..	39	44.3	86
Evening.....	5 p. m. to 8 p. m..	10	11.4	80
Night.....	8 p. m. to 5 a. m..	4	4.5	75

SUMMARY: BOTH TESTS.

Dawn.....	5 a. m. to 9 a. m..	24	11.3	77
Morning.....	9 a. m. to 1 p. m..	74	34.7	86
Afternoon.....	1 p. m. to 5 p. m..	68	31.9	90
Evening.....	5 p. m. to 8 p. m..	33	15.5	85
Night.....	8 p. m. to 5 a. m..	14	6.6	75

From this table it is seen that in the first test the greatest activity was exhibited in the morning period and the afternoon period ranked second, while in the second test the afternoon period was highest and the morning period was second. In both cases the night was the lowest of all.

The only other test of this sort which has been conducted was at Tallulah during 1910 when it was found that the afternoon period ranked first and the evening period was second. However, this test was conducted during July and the one this year was in August, so the results are not strictly comparable owing to differences in the light and temperature conditions during the various periods.

CESSATION OF OVIPOSITION BY HIBERNATED WEEVILS.

Observations on the date of cessation of oviposition were made with 45 hibernated females collected in the field early in the season and fed on cotton squares. As shown in Table XXI the dates ranged from June 9 to August 23 and the average date of cessation in both series was July 17. All the females excepting two laid eggs on June 20 or later and a majority laid eggs well along in July. Since these females were nearly all selected from the first to appear in the spring it is certain that the later emerged adults would continue to oviposit considerably longer in the fall. Thus the futility of late planting of cotton to escape boll weevil attack is seen.

TABLE XXI.—*Dates of cessation of oviposition of first hibernated females of the boll weevil.*

With males throughout life.		Females isolated from males in spring.		With males throughout life.		Females isolated from males in spring.	
Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.	Date collected.	Date stopped ovipositing.
May 26.....	Aug. 3	June 1	June 29	June 17	Aug. 23	do....	July 15
Do.....	June 9	do....	July 10	Do.....	July 18	do....	Aug. 13
Do.....	June 26	do....	Aug. 22	Do.....	July 14	do....	July 3
Do.....	June 29	do....	July 19	Do.....	June 20	do....	Aug. 23
Do.....	July 5	do....	July 21	Do.....	Aug. 4	do....	July 17
Do.....	June 28	do....	June 28	Do.....	Aug. 5	do....	June 26
Do.....	June 18	do....	July 8	Do.....	do....	do....	Aug. 20
Do.....	July 19	do....	July 19	Do.....	do....	do....	July 22
Do.....	July 10	do....	June 30	Do.....	do....	do....	July 24
Do.....	July 12	do....	Aug. 4	Do.....	do....	do....	July 3
Do.....	July 8	do....	July 4	Do.....	do....	do....	July 7
Do.....	July 31	do....	July 30	Earliest date stopped...	June 9	do....	June 26
Do.....	June 23	do....	Aug. 17	Latest date stopped...	Aug. 23	do....	Aug. 23
June 17.....	July 31	do....	July 17	Average date stopped...	July 13	do....	July 20

TOTAL DEVELOPMENTAL PERIOD.

Observations of 1914.—The time required from egg deposition to adult emergence was observed with all weevils bred in the various series until September 5. The maximum developmental period of any weevil was 20 days and the minimum period was 11 days. The results are tabulated according to season and generation in Table XXII.

TABLE XXII.—Total developmental period of the boll weevil: Observations of 1914.

Nature of weevils.	Larval food.	Period of oviposition.	Number males bred.	Male weevil days.	Average period.	Number females bred.	Female weevil days.	Average period.	Total number bred.	Total weevil days.	Average period.
				<i>Dys</i>			<i>Days.</i>			<i>Days.</i>	
First generation.	Cotton squares.	June 2-July 2.....	3	44	14.7	7	110	15.7	10	154	15.4
Second generation.	do.....	June 23-June 30.....	2	31	15.5	3	45	15	5	76	15.2
Do.....	do.....	July 1-5.....	11	170	15.5	18	269	14.9	29	439	15.2
Do.....	do.....	July 8-12.....	14	200	14.3	16	230	14.4	30	430	14.3
Do.....	do.....	July 13-20.....	50	753	15.1	41	603	14.7	91	1,356	14.9
Do.....	do.....	July 21-31.....	104	1,475	14.1	92	1,303	14.2	196	2,778	14.2
Do.....	do.....	Aug. 1-5.....	40	598	15	34	509	15	74	1,107	15
Do.....	do.....	Aug. 6-11.....	33	495	15	25	375	15	58	870	15
Do.....	do.....	Aug. 12-31.....	16	245	15.3	26	384	14.8	42	629	15
Do.....	do.....	Sept. 1-15.....	5	72	14.5	15	232	15.5	20	304	15.2
Total.....			275	4,039	14.7	270	3,950	14.6	545	7,989	14.6+
Third generation	do.....	July 15-21.....	20	279	14	17	242	14.2	37	521	14.1
Do.....	do.....	July 22-26.....	21	305	14.5	30	436	14.5	51	741	14.5
Do.....	do.....	July 27-31.....	14	204	14.6	13	187	14.4	27	391	14.5
Do.....	do.....	Aug. 2-10.....	14	208	14.9	22	330	15	36	538	15
Do.....	do.....	Aug. 11-24.....	9	127	14.1	11	164	15	20	291	14.6
Total.....			78	1,123	14.4	93	1,359	14.6	171	2,482	14.5
Fourth generation	do.....	Aug. 2-10.....	14	211	15.1	18	266	14.8	32	477	14.9
Do.....	do.....	Aug. 11-23.....	22	312	14.2	29	416	14.3	51	728	14.3
Total.....			36	523	14.5	47	682	14.5	83	1,205	14.5
Fifth generation.	do.....	Sept. 2-5.....	5	72	14.5	6	86	14.3	11	158	14.4
Total.....			397	5,801	14.6	423	6,187	14.6	820	11,988	14.6

During the entire season 397 males and 423 females were bred. The average developmental period for both sexes was 14.6 days. Weevils bred later than September required a much longer developmental period but no positive record was kept of these weevils.

Observations of 1915.—The total developmental periods of all weevils observed during 1915 is detailed in Table XXIII.

TABLE XXIII.—*Total developmental period of the boll weevil: Observations of 1915.*

GRANDIS WEEVILS.

Source of weevils.	Larval food.	Oviposition period.	Males.			Females.			Total number bred.	Total weevil days.	Average period.
			Number bred.	Weevil days.	Average period.	Number bred.	Weevil days.	Average period.			
Hibernated weevils....	Cotton squares	June 1–Aug. 23..	97	1,383	14.3	105	1,443	13.7	202	2,826	14
Do.....	do.....	June 2–Aug. 23..	91	1,264	13.9	87	1,193	13.7	178	2,457	13.8
First generation.....	do.....	June 26–Sept. 7..	44	629	14.3	54	739	13.7	98	1,368	14
Second generation.....	do.....	July 23–Sept. 5..	6	93	15.5	9	131	14.6	15	224	14.9
<i>Grandis</i> bred weevils..	Cotton bolls...	July 12–Sept. 16.	7	115	16.4	13	209	16.1	20	324	16.2
Total.....	.....	.....	245	3,484	14.2	268	3,715	13.9	513	7,199	14

THURBERIAE WEEVILS.

Weevil extracted from bolls.	Cotton squares	June 28–Sept. 9..	55	792	14.4	49	709	14.47	104	1,501	14.43
First generation.....	do.....	July 24–Sept. 20.	16	234	14.6	7	95	13.6	23	329	14.3
Extracted from bolls...	Cotton bolls...	July 28–Sept. 24.	4	57	14.3	6	97	16.3	10	154	15.4
Total.....	.....	.....	75	1,083	14.4	62	901	14.5	137	1,984	14.48

HYBRIDS.

Male <i>grandis</i> by female <i>thurberiae</i> .	Cotton squares	June 28–Sept. 7..	50	689	13.78	63	827	13.13	113	1,516	13.42
Male <i>thurberiae</i> by female <i>grandis</i> .	do.....	June 28–Sept. 19.	52	726	14.0	51	719	14.1	103	1,445	14
Total of all varieties.	.....	1915.....	422	5,982	14.2	444	6,162	13.9	866	12,124	14

The average total period for both sexes in both squares and bolls was 14 days. The developmental period in bolls is seen to be greater than in squares with both *grandis* and *thurberiae* weevils. In cotton bolls the *grandis* weevils averaged 16.2 days and the *thurberiae* weevils averaged 15.4 days.

The total developmental period for females is slightly shorter than for the males, which agrees with the observations at Victoria, Tex., in 1913. The average developmental period is apparently a day or more shorter at Tallulah than at Victoria in the same season. There seems to be no difference of note in the records for the various years.

In addition to these studies an experiment was conducted to determine the relative length of the developmental period in squares and bolls when the eggs were deposited by the same female. For this purpose 11 pairs of bred *grandis* were mated on cotton squares until they started normal deposition; then they were given squares and bolls on alternate days and the eggs deposited in them were saved for adult emergence. The comparison of the results is shown in Table XXIV.

TABLE XXIV.—Comparative developmental period of the boll weevil in squares and bolls from eggs deposited by females offered these foods on alternate days.

[illegible]

Here it is seen that the weevils reared from squares averaged 15 days while those from bolls averaged 16.7 days. The comparative percentages of eggs producing adults are also interesting. Of those laid in squares, 12.1 per cent produced adults while 33.1 per cent of those in bolls produced adults. This is undoubtedly due to the fact that some of the squares were too small to feed the larvæ to maturity and also to the fact that when two or more eggs hatch in the same square the shortage of food usually results fatally to both. The greater deposition in the squares is very marked.

EFFECT OF SIZE OF SQUARE ON WEEVIL DEVELOPMENT.

In July, 1915, an experiment was conducted to determine the effect of the size of the cotton square on the weevil developmental period. An abundance of clean squares was placed in a large wire cage with fertile females and left for one day. The squares containing single eggs were separated into lots of 50 squares each; one lot being small squares, one medium-sized, and the third large. The small squares produced one weevil in 14 days, the medium-sized squares produced 20 weevils in an average of 14.1 days, and the large squares produced 18 weevils in an average of 14.5 days. While the number of weevils reared is too small to make the results conclusive, it seems that the length of the developmental period is directly proportional to the amount of food available. This appears quite probable in view of the fact that the developmental period is always considerably longer in cotton bolls than in cotton squares. The small squares seemed not to furnish sufficient food for the weevil development as only one weevil was able to reach maturity in the 50 tested.

GENERATIONS.

One series of weevils was carried through the season of 1914 to determine the maximum number of generations possible in cotton squares in one year. For starting the series hibernated females were collected immediately after emergence in the spring and placed with males on cotton squares. The first eggs of these females were saved and the progeny reared. The first adults to mature from these were mated and their first eggs secured. This procedure was followed through the season, and the results are shown in Table XXV. Between the first of June and the first of November these weevils were carried through seven generations, the first and only weevil of the seventh generation emerging November 1. This individual was very weak and died in a few days, but as the cold weather at this time had stopped all breeding in the field it was evident that the limit of the breeding season had been reached.

TABLE XXV.—*Number of generations of the boll weevil: Maximum series on squares.*

Generation.	Date.	Period from maturity to maturity.
		<i>Days.</i>
First generation:		
Eggs laid	June 1	
Generation mature	June 22	
Second generation:		
Eggs laid	June 23	
Generation mature	July 9	18
Third generation:		
Eggs laid	July 15	
Generation mature	July 28	20
Fourth generation:		
Eggs laid	Aug. 2	
Generation mature	Aug. 18	22
Fifth generation:		
Eggs laid	Sept. 2	
Generation mature	Sept. 17	31
Sixth generation:		
Eggs laid	Sept. 18	
Generation mature	Oct. 8	22
Seventh generation:		
Eggs laid	Oct. 13	
Generation mature	Nov. 1	24

At Victoria in 1913 the weevils were carried through the same procedure and the same number of generations secured. However, the first hibernated females at Victoria were secured over a month earlier than those at Tallulah and the breeding continued a few days longer in the fall. In other words, the generations were sufficiently shorter at Tallulah to allow the same number to be produced in more than a month less than at Victoria.

SUMMARY.

In northern Louisiana the average longevity of the boll weevil adults on cotton squares was 54.56 days; on bolls 31.41 days; on cotton leaves 8.17, and on okra fruit 5.4, the average for these different classes of foods being 14.13 days.

The females live somewhat longer than the males, there being an average of 12.5 days for females and 9.82 for males.

A number of weevils were found feeding in okra blooms in the field but attempts to cause them to breed in okra fruit in the laboratory were unsuccessful. A number of eggs were deposited but they failed to hatch.

The largest number of eggs deposited by the first generation weevils was 204, the average being 132. The daily maximum varied from 5 to 12. Second generation weevils showed somewhat less fecundity, the maximum oviposition being 175 eggs and the average 69.4.

The average period of oviposition was 38.2 days, the range being 1 to 77 days.

The greatest activity of the weevil in depositing eggs was found to be between the hours of 9 a. m. and 1 p. m., but certain numbers of eggs were deposited at all times of the day and during the night.

The average period from oviposition to the emergence of the adult was practically 14 days for each of the five generations.

Seven complete generations were developed at Tallulah during the season.

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PROFESSIONAL PAPER.

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COMPARATIVE SPINNING TESTS OF THE DIFFERENT GRADES OF ARIZONA-EGYPTIAN WITH SEA ISLAND AND SAKELLARIDIS EGYPTIAN COTTONS.

By FRED TAYLOR, *Cotton Technologist* and WILLIAM S. DEAN, *Assistant in Cotton Testing*.

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INTRODUCTION.

The introduction and development of long-staple cotton in the Salt River Valley of Arizona is described fully in previous bulletins published by the United States Department of Agriculture.¹ With these publications available, the purpose of this bulletin will be to deal exclusively with the adaptability of this cotton for manufacturing purposes.

Not until the last few years has the production of Arizona-Egyptian cotton been sufficient in quantity to interest the manufacturer materially. The estimated production figures are as follows: In 1912, 280 bales; in 1913, 2,200 bales; in 1914, 6,187 bales. On account of abnormal conditions, the acreage for 1915 was reduced approximately 50 per cent with a corresponding reduction in the yield. Information, however, is at hand, which indicates an increase in acreage for the season of 1916.

¹ See Bureau of Plant Industry Bulletin No. 128, "Egyptian Cotton in the Southwestern United States;" Department Bulletin No. 38, "Seed Selection of Egyptian Cotton;" Department Bulletin No. 332: "Community Culture of Egyptian Cotton in the United States," and the list of publications given on the last page of this bulletin. For grade factors see Department Bulletin No. 311, "The Handling and Marketing of the Arizona-Egyptian Cotton of the Salt River Valley."

NOTE.—This bulletin is of interest to the growers, cotton merchants, manufacturers and dealers in Arizona-Egyptian, Sea Island, and Sakellaridis Egyptian cottons and cotton yarns.

PURPOSE OF THE SPINNING TESTS.

Because of the remarkable increase in the production of this cotton, it has seemed advisable to accumulate reliable data relative to the character of Arizona-Egyptian cotton for manufacturing purposes. This cotton closely resembles the Sakellaridis Egyptian cotton in color, character, and length of fiber and in many respects compares favorably with the Sea Island cotton of Georgia and Florida. Spinning tests have been conducted by the Department of Agriculture to develop information along the following lines: First, the different grades of Arizona-Egyptian cotton were compared with each other as to their spinning qualities, viz, waste, tensile strength, bleaching, mercerization, dyeing and finishing qualities; and, second, the Arizona-Egyptian cotton was compared with Sakellaridis Egyptian and Sea Island cottons.

As these cottons can be substituted for each other to some extent in the manufacture of certain classes of goods, it is believed that reliable spinning tests will prove of general interest in bringing out the individual merits of these varieties.

Tests ¹ were conducted on the 1914 crop during the summer of 1915 on the following lots of cotton, namely, four bales of Arizona-Egyptian cotton—one of each of the grades, Extra, Choice, Standard, and Medium; three bales of Sakellaridis Egyptian cotton, shipped from Alexandria, Egypt, marked MERR, CONN, and EDM, of the grades Good, Fully Good Fair, and Fair; and two bales of Sea Island cotton shipped from Blackshear, Ga., of the grades Fancy and Extra Choice. The bales of Sea Island cotton originated no doubt in the interior and were slightly different in character from the longer length staples of Sea Island cottons grown on the islands and the coast. One hundred pounds of each of these bales were used in making the tests.

MECHANICAL CONDITIONS.

In each test the cotton was opened and left standing overnight before being fed into the first machine. The machines were kept in good working order and sufficient time was taken between each run to clean them thoroughly. Total weights were taken immediately before and after the cotton was fed into the opener, finisher, cards and combers, respectively. Each kind of cotton up to the slubber was run through the same machines and subjected to practically the same speeds, settings, drafts, etc. In the manufacture of yarn, numbers 10's, 20's, 30's, 40's, 50's, 60's, 80's and 100's, from each kind of cotton, the same weight of lap and sliver was used up to the slubber. This was done in order to have the cleaning machinery operate under

¹ Through the courtesy of Mr. William E. Hatch, President, these tests were conducted at the New Bedford Textile School, New Bedford, Mass., under the supervision of Mr. Fred Taylor. Mr. W. S. Dean was directly in charge of the work, assisted by Messrs. J. J. W. Cooper and T. C. Adams.

exactly the same conditions for each kind of cotton used, so that the waste percentages might be comparable.

The different lots of cotton were run on the same fly or roving frames and spinning frames throughout for the different numbers of yarn; that is, all cotton going into any certain number of yarn was subjected to the treatment of the same machines, and, where possible, the different lots were placed and run simultaneously through each process. Table I gives the respective drafts used in these machines.

TABLE I.—*Drafts used in the manufacture of each number of yarn.*

Num- bers.	Slubber.	First interme- diate.	Second interme- diate.	Jack frame.	Spinning frame.
10's ...	3	4	5	.....	8
20's ...	3	4.5	6	.....	11.9
30's ...	3	4	5	6	8.26
40's ...	3	4	5	6.42	10
50's ...	3	4.17	5.5	7	10
60's ...	3	4.5	6	7.12	10
80's ...	3.63	5	6	7	10
100's ...	4	5.30	6.25	7.25	10

While the cotton was being manufactured, the humidity conditions were kept as nearly constant as possible. Records were taken hourly and the humidifiers were regulated accordingly. Records were taken also every thirty minutes during the time the tensile strength tests were being conducted. The desired point of relative humidity was 55 per cent in the raw cotton and picker rooms, 55 to 60 per cent in the card room, 60 to 65 per cent in the spinning room, and 65 per cent in the yarn-testing room. Moisture tests were made also on samples of cotton selected from each place in the processes where the stock was weighed, and it was found that the differences in the percentages of moisture were comparatively small.

The spinning qualities of the different lots of cotton were judged in the following manner:

A broken end on a spinning frame was not pieced up until determinations were made as to the causes of the breakage. All ends breaking down, unless due to some mechanical defect, were charged against the particular grades or lots in which they occurred, and notations were made as to the amount of fly waste from the different lots.

There was no conclusive evidence of superiority in any one lot over any other in spinning. In a number of cases, the bobbins of each lot filled up on the spinning frames without an end breaking down.

GRADE, STAPLE, AND PRICE COMPARISONS.

In order to understand better the comparative relations between the lots of cotton to be used, samples were presented to a committee of cotton specialists of the Office of Markets and Rural Organization. It was thought that, judging from the general appearance of the different

cottons from the standpoint of grade, the following comparisons would be fair:

Extra Arizona-Egyptian to be compared with Fancy Sea Island.

Choice Arizona-Egyptian to be compared with Extra Choice Sea Island, also against Good Sakellaridis Egyptian.

Standard Arizona-Egyptian to be compared with Fully Good Fair Sakellaridis Egyptian.

Medium Arizona-Egyptian to be compared with Fair Sakellaridis Egyptian.

This committee estimated the length of staple as shown in Table II.

TABLE II.—*Length of staple of cotton used in the tests.*

Arizona-Egyptian.		Sea Island.		Sakellaridis Egyptian.	
Grade.	Inches.	Grade.	Inches.	Grade.	Inches.
Extra.....	1½	Fancy.....	1⅞	Good.....	1⅞
Choice.....	1½	Extra Choice.....	1⅞	Fully good fair....	1⅞
Standard.....	1½			Fair.....	1⅞
Medium.....	1½				

Individual fibers of these cottons were also measured by the projection device originated by Dr. N. A. Cobb of this department, and it was found that the ratio of lengths between the estimated lengths and the actual measurements was relatively uniform.

Samples of this cotton were sent to certain reputable cotton brokers who deal in staple cotton to ascertain the comparative commercial value of each bale on the same day. Data were given these brokers regarding the origin of each bale of cotton, so that all factors influencing the commercial value could be considered. Table III shows the result of this inquiry.

TABLE III.—*Price per pound of cotton used in the tests.*

Arizona-Egyptian.		Sea Island.		Sakellaridis Egyptian.	
Grade.	Price per pound.	Grade.	Price per pound.	Grade.	Price per pound.
Extra.....	\$0.21	Fancy.....	\$0.21½	Good.....	\$0.21½
Choice.....	.20½	Extra choice.....	.20½	Fully good fair....	.20½
Standard.....	.19½			Fair.....	.19½
Medium.....	.18				

WASTE COMPARISONS.

The results obtained from the tests, already described, to determine the amount of waste in each kind and variety of cotton are shown in Table IV. This table gives the waste percentages based on the amount of cotton fed into each machine. The tare on the bales of cotton was not included in any case.

TABLE IV.—Waste percentages based on net amount of cotton fed into each machine.

Machines.	Kind of waste.	Arizona-Egyptian.				Sea Island.		Sakellaridis Egyptian.		
		Extra.	Choice.	Stand- ard.	Me- dium.	Fancy.	Extra choice.	Good.	Fully good fair.	Fair.
Opener....	Visible:									
	Dust room.....	0.25	0.187	0.375	0.375	0.319	0.312	0.521	0.314	0.189
	Opener, motes and fly.....	.312	.25	.25	.187	.510	.312	.260	.251	.757
	Breaker, motes and fly.....	.687	.562	.937	.749	.765	.625	.911	1.067	.567
	Total visible.....	1.249	.999	1.562	1.311	1.594	1.249	1.692	1.632	1.513
	Invisible.....	.937	.....	.5	.5	1.531	.937	1.043	1.444	.946
Finisher....	Total visible and invisible.....	2.186	.999	2.062	1.811	3.125	2.186	2.735	3.076	2.459
	Visible:									
	Dust room.....	.067	.068	.068	.068	.137	.067	.077	.069	.07
	Motes and fly.....	.674	.617	.546	.751	.617	.535	.850	1.111	1.032
	Total visible.....	.741	.685	.614	.819	.754	.602	.927	1.180	1.122
	Invisible.....	.134	a.411	.341	.341	.....	.267	.540	.069	.140
Cards.....	Total visible and invisible.....	.875	.274	.955	1.160	.754	.869	1.467	1.249	1.262
	Visible:									
	Flat strippings.....	3.233	3.832	3.905	3.574	5.203	5.702	3.925	4.804	4.705
	Cylinder and doffer strippings.....	1	1.179	1.252	1.216	1.069	1.140	1.373	1.552	1.47
	Motes and fly.....	.769	1.031	1.031	1.216	.855	.926	1.275	1.551	1.837
	Total visible.....	5.002	6.042	6.188	6.006	7.127	7.768	6.573	7.907	8.012
Combers...	Invisible.....	.384	.368	.442	.988	a.213	a.427	1.472	a.369	1.397
	Total visible and invisible.....	5.386	6.410	6.630	6.994	6.914	7.341	8.045	7.538	9.409
	Visible.....	11.127	11.764	12.811	12.406	13.675	14.529	15.981	16.362	16.408
	Invisible.....	a.867	.110	a.088	a.093	.756	a.2	a.822	.435	a.257
	Total visible and invisible.....	10.260	11.874	12.723	12.313	14.431	14.329	15.159	16.797	16.151

a Invisible gain, not loss, as result of weather conditions.

There seems to be no significant relationship between the grade of Arizona-Egyptian cotton and the percentage of waste or between the variety of cotton and the amount of waste discarded, when the percentage of waste is considered at any of the individual processes of manufacture. Arizona-Egyptian cotton, however, shows more uniformity in this respect than any other, with the Sea Island second. By referring to Table V which represents the total amount of waste taken from the different processes computed on the original amount fed into the opener, it will be noticed that there seems to be some uniformity of relationship between the percentages of waste and the different grades of Arizona-Egyptian cotton, ascending in order of grade, as follows: Extra, 17.69 per cent; choice, 18.56 per cent; standard, 20 per cent; and medium, 20.90 per cent. The average percentage of waste of each variety is, Arizona-Egyptian cotton, 19.28; Sea Island, 23.23; and Sakellaridis, 26.57.

TABLE V.—*Total visible and invisible waste.*

[Percentages based on the original amount of cotton fed into the opener.]

Machines.	Arizona-Egyptian.				Sea Island.		Sakellaridis Egyptian.		
	Extra.	Choice.	Stand-ard.	Me-dium.	Fancy.	Extra choice.	Good.	Fully good fair.	Fair.
Pickers.....	3.05	1.27	2.99	2.95	3.86	3.04	4.17	4.29	3.69
Cards.....	5.22	6.32	5.47	6.83	6.65	7.12	7.72	7.22	9.06
Combers.....	9.42	10.97	11.54	11.12	12.91	12.89	13.47	14.87	15.22
Total.....	17.69	18.56	20.00	20.90	23.42	23.05	25.36	26.38	27.97

Judging from the general appearance and grade of Arizona-Egyptian cotton against similar grades of the other cottons (see comparisons on p. 4) the spinning values, as shown by the amount of waste discarded in the manufacturing processes, apparently, are not evident in the raw cotton. The grades, as previously arranged for comparison, seem to be equal in value, but when subjected to the manufacturing processes, the cottons prove to be decidedly unequal, the difference being in favor of the Arizona-Egyptian cotton as follows:

Extra Arizona-Egyptian shows 5.73 per cent less waste than Fancy Sea Island.

Choice Arizona-Egyptian shows 4.49 per cent less waste than extra choice Sea Island.

Choice Arizona-Egyptian shows 6.80 per cent less waste than good Sakellaridis Egyptian.

Standard Arizona-Egyptian shows 6.38 per cent less waste than fully good fair Sakellaridis Egyptian.

Medium Arizona-Egyptian shows 7.07 per cent less waste than fair Sakellaridis Egyptian.

Choice Arizona-Egyptian is the only individual bale of cotton that is compared with both Sea Island and Sakellaridis cotton. The Arizona-Egyptian shows 4.49 per cent less waste than the Sea Island, and the Sea Island shows 2.31 per cent less waste than the Sakellaridis. These figures indicate very clearly that of the three lots tested the Arizona-Egyptian was considerably less wasty than Sea Island, and Sea Island considerably less than the Sakellaridis. Figure 1 represents graphically these waste percentages.

By referring again to the relative prices of these different cottons, as given in Table III, it will be seen that there was a relation between the prices and the grades, but there was no relation whatever between the prices of the different lots of cotton and the percentages of waste discarded from each lot in the manufacturing processes.

Rather a reverse condition was demonstrated, that is, the Arizona-Egyptian cotton that was represented as being of least value in cents per pound was in reality the cotton that discarded the least waste in the manufacturing processes. This comparison of equivalent grades (see p. 4) will be found in Table VI.

TABLE VI.—Prices of the different grades of each lot of cotton in comparison with the percentages of waste discarded.

[Bales arranged in groups according to the apparent grade relation of the different lots.]

	Arizona extra.	Sea Island fancy.	Arizona choice.	Sea Island extra choice.	Sakellaridis good.	Arizona stand.	Sakellaridis fully good fair.	Arizona medium.	Sakellaridis fair.
Price of cotton.....	\$0.21	\$0.21½	\$0.20½	\$0.20½	\$0.21½	\$0.19½	\$0.20½	\$0.18	\$0.19½
Percentage of waste.....	17.69	23.42	18.56	23.05	25.36	20.00	26.38	20.90	27.97

It should be borne in mind that all the cotton represented as waste is not actually lost, but the greater part of it is reworked in the manufacture of cheaper goods.

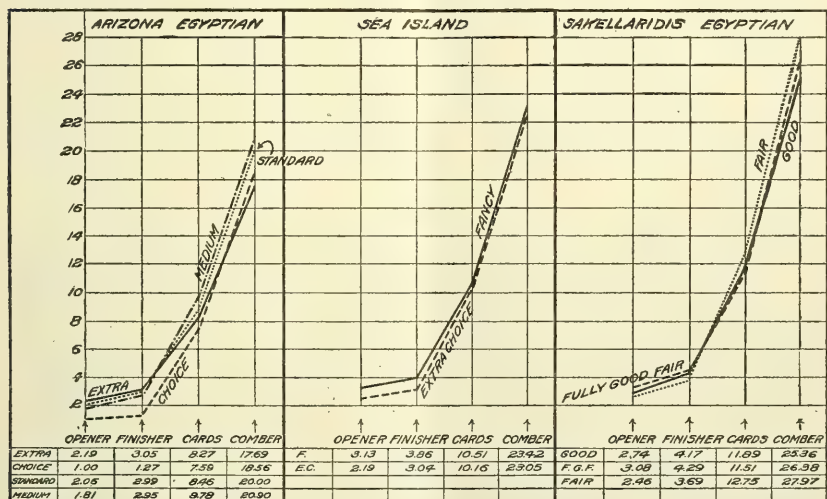


FIG. 1.—Progressive waste percentages of Arizona-Egyptian, Sea Island, and Sakellaridis Egyptian cottons.

TENSILE STRENGTH COMPARISONS.

In order to ascertain the difference in tensile strength between the grades of Arizona-Egyptian cotton and between Arizona-Egyptian, Sakellaridis Egyptian, and Sea-Island cottons, there were manufactured from each of these the following numbers of yarn: 10's, 20's, 30's, 40's, 50's, 60's, 80's, and 100's. The slight variations in the numbers of yarn were standardized on a weight basis. A portion of this cotton yarn was spun with two twist constants,¹ viz, 3.25 and 3.80.

¹ Multiply the square root of the number of yarn by the constant to find the turns per inch of twist inserted in the yarn while spinning.

TABLE VII.—*Average breaking strength of single threads arranged in order, for comparison according to grade relations.*

[With twist per inch as indicated by the twist constant.]

Twist constant.	Num- bers of yarn.	Extra Ari- zona.	Fancy Sea Island.	Choice Ari- zona.	Extra choice Sea Island.	Good Sakel- laridis.	Stand- ard Ari- zona.	Fully good fair Sakel- laridis.	Medi- um Ari- zona.	Fair Sakel- laridis.
3.80.....	30's	14.88	15.35	15.13	14.99	15.87	14.96	15.31	14.54	14.93
3.80.....	60's	4.29	4.53	3.88	4.50	4.35	4.18	4.60	4.10	4.25
3.25.....	60/2	11.54	12.02	10.85	11.43	11.91	11.85	12.25	12.08	12.01
3.80.....	100's	2.09	2.23	2.01	2.14	2.03	2.13	2.16	2.02	1.98
3.25.....	100's	1.77	2.02	1.82	1.92	2.00	1.94	1.78	1.92	1.69
Average.....		6.91	7.23	6.74	7.00	7.23	7.01	7.22	6.93	6.97

Table No. VII gives the results obtained from a single thread-testing machine. The table is arranged for comparing the different yarns with the various kinds of cotton according to grade. The results here seem to be somewhat in favor of the Sakellaridis-Egyptian cotton, with Sea Island coming second, but where extra choice Sea Island is compared with good Sakellaridis, out of five numbers of yarn produced, the Sea Island is stronger than the Sakellaridis in two cases.

The single-thread tests ¹ were made more for the purpose of ascertaining the relative uniformity in the strength of the different yarns than for the average breaking strength. From this point of view there was no decided difference between the cottons tested.

The tensile strength of the yarn was obtained in the laboratory at Washington by reeling off skeins of 120 yards each from the various grades and kinds of cotton. These skeins were placed on racks in order to keep them separate and untangled. A power yarn tester was used, the downward stroke of the traverse moving at the rate of approximately 12 inches per minute. The humidity was kept as nearly constant as possible by taking records with a sling psychrometer every half hour and regulating the humidifier in the testing room. The desired point of relative humidity was 65 per cent. The skeins were taken one at a time in rotation from the different racks and broken. They were then weighed and the results recorded. This operation was repeated, usually 24 times, until the average breaking strengths shown in Tables VIII and IX were ascertained. From these tables it will be seen that there is no significant relationship between the breaking strength of the different grades of Arizona-Egyptian cotton.²

¹ All single-thread tests were made at the New Bedford Textile School, New Bedford, Mass., by William Smith, principal in charge of the carding and spinning department of this school, who also furnished generous assistance throughout all these tests.

² See Bureau of Plant Industry Circular No. 110.

TABLE VIII.—Average breaking strength in pounds per skein of 120 yards of the different numbers of yarn.

[With twist per inch of 3.25 times the square root of number of yarn.]

Numbers of yarn.	Arizona-Egyptian.				Sea Island.		Sakellaridis Egyptian.		
	Extra.	Choice.	Stand-ard.	Medi-um.	Fancy.	Extra choice.	Good.	Fully good fair.	Fair.
10's.....	352.66	332.29	329.60	314.37	306.08	320.14	341.99	330.43	301.24
20's.....	166.93	162.78	163.90	160.09	163.53	164.29	168.54	166.10	160.18
30's.....	100.09	96.54	96.88	95.89	101.78	97.55	98.88	100.41	96.44
40's.....	66.42	67.34	70.11	68.18	74.44	71.56	71.25	72.19	69.57
50's.....	50.49	49.22	48.34	48.62	53.56	50.27	51.84	50.79	48.78
80's.....	25.34	25.23	23.87	23.66	27.45	25.25	24.97	24.26	23.66
100's.....	17.07	17.89	17.96	17.34	20.25	18.78	18.14	18.56	15.24
Average breaking strength.	111.28	107.33	107.24	104.02	106.73	106.83	110.80	108.96	102.16

TABLE IX.—Average breaking strength in pounds per skein of 120 yards of the different numbers of yarn.

[With twist per inch of 3.8 times the square root of number of yarn.]

Numbers of yarn.	Arizona-Egyptian.				Sea Island.		Sakellaridis Egyptian.		
	Extra.	Choice.	Stand-ard.	Medi-um.	Fancy.	Extra choice.	Good.	Fully good fair.	Fair.
30's.....	98.29	93.66	96.40	96.11	99.39	100.74	102.11	98.43	95.51
40's.....	73.43	70.13	70.12	67.21	72.70	70.17	73.04	72.23	68.72
50's.....	48.30	49.00	48.03	47.78	50.98	47.96	52.39	48.89	48.41
60's.....	39.63	39.11	39.45	39.06	41.93	38.78	41.25	39.49	39.09
80's.....	24.42	24.15	23.62	23.38	26.26	24.41	25.14	24.33	23.02
100's.....	17.82	18.00	17.81	17.23	20.24	18.48	18.08	18.61	16.82
Average breaking strength.	50.31	49.01	49.24	48.46	51.92	50.09	52.00	50.33	48.59

The same figures are used in Tables X and XI as were used in Tables VIII and IX, respectively. The latter tables, however, are designed to show the comparison in breaking strength between the different grades of the same variety of cotton, while the former tables show the comparison between the nearest equivalent grades of the different varieties of cotton. There is no uniformity in regard to the superiority of one of these lots of cotton over the other, considering the same number of yarn from the different lots. For instance, in Table X, of the four comparisons made with No. 10's yarn, Arizona-Egyptian was stronger than either of the other yarns for two of the comparisons, and Sakellaridis was stronger than the other yarns for the other two comparisons. Sea Island cotton for this number was apparently weaker than either, but by comparing 80's and 100's yarns, the conditions were practically reversed; that is, the Sea Island proved to be the strongest.

TABLE X.—Average breaking strength in pounds per skein of 120 yards of the different numbers of yarn arranged to show comparison according to grade relations.

[With twist per inch of 3.25 times the square root of the number of yarn.]

Numbers of yarn.	Extra Arizona.	Fancy Sea Island.	Choice Arizona.	Extra choice Sea Island.	Good Sakellaridis.	Standard Arizona.	Fully good fair Sakellaridis.	Medium Arizona.	Fair Sakellaridis.
10's.....	352.66	306.08	332.29	320.14	341.99.	329.60	330.43	314.37	301.24
20's.....	166.93	163.53	162.78	164.29	168.54	163.90	166.10	160.09	160.18
30's.....	100.09	101.78	96.54	97.55	98.88	96.88	100.41	95.89	96.44
40's.....	66.42	74.44	67.34	71.56	71.25	70.11	72.19	68.18	69.57
50's.....	50.49	53.56	49.22	50.27	51.84	48.34	50.79	48.62	48.78
60's.....	25.34	27.45	25.23	25.25	24.97	23.87	24.26	23.66	23.66
80's.....	17.07	20.25	17.89	18.78	18.14	17.96	18.56	17.34	15.24
Average breaking strength.	111.28	106.73	107.33	106.83	110.80	107.24	108.96	104.02	102.16

TABLE XI.—Average breaking strength in pounds per skein of 120 yards of the different numbers of yarn arranged to show comparison according to grade relations.

[With twist per inch of 3.8 times the square root of the number of yarn.]

Numbers of yarn.	Extra Arizona.	Fancy Sea Island.	Choice Arizona.	Extra choice Sea Island.	Good Sakellaridis.	Standard Arizona.	Fully good fair Sakellaridis.	Medium Arizona.	Fair Sakellaridis.
30's.....	98.29	99.39	98.66	100.74	102.11	96.40	98.43	96.11	95.51
40's.....	73.13	72.70	70.13	70.17	73.04	70.12	72.23	67.21	68.72
50's.....	48.30	50.98	49.00	47.96	52.39	48.03	48.89	47.78	48.41
60's.....	30.63	41.93	39.11	38.73	41.25	39.45	39.49	39.06	39.69
80's.....	21.42	26.26	24.15	24.41	25.14	23.62	24.33	23.38	23.02
100's.....	17.52	20.24	18.00	18.48	18.08	17.81	18.61	17.23	16.82
Average breaking strength	50.31	51.92	49.01	50.09	52.00	49.24	50.33	48.46	48.59

A careful analysis of these tensile strength tables discloses the fact that if comparisons of each kind of cotton and each number of yarn are made, the yarns manufactured from the Sakellaridis Egyptian cotton were proportionately stronger in the greatest number of cases, the yarns made from the Sea Island ranked second, while those made from Arizona-Egyptian cotton were lowest in tensile strength. There were, however, considerable variations, showing that first one kind of cotton and then another was superior in breaking strength on the different numbers of yarn. These variations might be taken as indications that each different kind of cotton is best adapted to certain numbers of yarn. It seems more probable, however, that these small differences would exist naturally in the manufacture of any two lots of cotton of even the same kind. The average of the tensile strength of all the different numbers of yarn with 3.25 as twist constant compared according to the grade arrangements given in Table X shows that in two cases out of four Arizona-Egyptian is the strongest, and in two cases Sakellaridis is the strongest. The average tensile strength of all the different numbers of yarn with twist constant of 3.80 as shown in Table XI shows that Sea Island is strongest in one case and Sakellaridis in three cases.

Referring again to page 6, it may be seen that the comparisons between the three grades of Arizona-Egyptian and Sakellaridis Egyptian show that the average differences in waste cotton were 6.80 per cent, 6.38 per cent, and 7.07 per cent, respectively, in favor of the Arizona-Egyptian. In the comparisons of the two grades of Sea Island cotton with Arizona-Egyptian there were differences of 4.49 per cent and 5.73 per cent, respectively, in favor of the Arizona-Egyptian.

The tensile strength of the yarns made from the different cottons is affected by the percentage of waste discarded. Therefore, where the differences in waste are so evident, in order to make a more comprehensive determination as to the comparative tensile strength, it would seem advisable to remove the same amount of waste from each kind of cotton.

BLEACHING, DYEING, AND MERCERIZING.

Investigations were made to ascertain the relative values of Arizona-Egyptian, Sea Island, and Sakellaridis cottons as to their bleaching, dyeing, and mercerizing qualities. These tests¹ were made upon both loose cotton and yarns. The following numerical designations arbitrarily represent the different grades and kinds of cotton. For example, 1 to 4 represents Arizona-Egyptian, 5 to 6, Sea Island, and 7 to 9, Sakellaridis.

Number.	Grade.	Kind.
1.....	Extra.....	Arizona-Egyptian.
2.....	Choice.....	Do.
3.....	Standard.....	Do.
4.....	Medium.....	Do.
5.....	Fancy.....	Sea Island.
6.....	Extra choice.....	Do.
7.....	Good.....	Sakellaridis Egyptian.
8.....	Fully good fair.....	Do.
9.....	Fair.....	Do.

BLEACHING LOOSE COTTON.

The different methods used in bleaching will be referred to as methods (a), (b), (c), (d), (e), (f), (A), and (B).

Method (a).—The cotton was bleached by treating it, without scouring, with a solution, obtained by the electrolysis of salt, containing 0.5 grams of chlorine per liter. In the future this solution will be designated as “electrolitic chlorine.”

Method (b).—The cotton was scoured in a solution containing 1 gram of soda ash in each 10 cubic centimeters; then bleached as in (a).

Method (c).—The cotton was treated with 2 per cent acetic acid and bleached as in (a).

¹ These tests were made at the New Bedford Textile School in the laboratory of the department of chemistry, by Everett H. Finckley, professor in charge of this department.

Finally all the samples were blued with 0.001 per cent of blue violet acid dye.

These three methods represent the usual means taken to obtain white cotton for spinning, except that the quantity of bleaching agent used was reduced in order to magnify any variations in the results obtained.

Method (d).—The cotton was boiled two hours in a 10 per cent solution of soda ash and bleached cold in electrolytic chlorine containing 2 grams of chlorine per liter.

Method (e).—The cotton was treated as in (d) except that a chloride lime solution, containing 8 grams of chlorine per liter was used for the bleaching agent.

Method (f).—The cotton was treated as in (d) except that an alkaline solution of sodium peroxide equivalent to 15 grams of chlorine per liter was used.

After bleaching, all the samples were blued as in processes (a), (b), and (c). The above concentrations of bleaching agent represent those used in commercial practice to obtain equal bleaching results.

Method (A).—The cotton was treated cold for two hours in a 2-degree Twaddle solution of bleaching powder, containing 5.82 grams of chlorine per liter; rinsed with cold water; soured with 2 per cent solution of acetic acid; rinsed and antichlored in a 2 per cent solution of sodium bisulphite 30 minutes; then finally rinsed and blued in water containing 1 gram of "Vat Blue" in each 13½ liters.

Method (B).—The cotton was treated as in method (A), except that a solution of electrolyzed salt, containing 2.87 grams per liter of available chlorine was used as a bleaching agent.

Laboratory samples of the cottons were bleached by methods (a), (b), and (c). The Arizona-Egyptian cotton bleached more easily than did the Sakellaridis, and very closely resembled the Sea Island in this respect.

Samples were also bleached of each of the cottons by methods (d), (e), and (f). The results obtained by these tests were negative, as the treatment was sufficiently severe to have produced the same white on all of them.

Finally, 2-pound lots were treated according to method (B), and the results obtained matched against a series of standard whites. Table XII shows the results of this comparison.

TABLE XII.—*Bleached cotton of the respective grades and lots matched against a series of standard whites.*

	Arizona-Egyptian.				Sea Island.		Sakellaridis.		
	1	2	3	4	5	6	7	8	9
Set.....	3	3	3	3	3	3	3	3	3
Standard.....	7	8	8	7	6	8	7	7	7

The above standards consist of set No. 1, a range of yellow tints; set No. 2, a range of blue tints; and set No. 3, a range of red tints. The better the bleach obtained, the less yellow would be apparent, hence such samples would find their match in set No. 2 or No. 3. In each set there were 10 standards, varying with regular increasing intensity of tint, the higher numbers having the highest color. Hence from the above tables it will be seen that the Arizona-Egyptian in case of samples No. 1 and No. 4 gave shades equal to the true Egyptian, and in the case of samples No. 2 and No. 3 gave shades equal to the best obtained on the Sea Island.

BLEACHING YARNS.

Yarns made from the cotton designated No. 1 to 9 (p. 11) were used in the bleaching tests. The bleaching of these yarns was carried on according to methods (A) and (B). The whites obtained were matched against the standards with the results given in Table XIII. This table shows that with either method of bleaching, better whites were obtained with the Arizona-Egyptian and Sea Island than with the Sakellaridis.

TABLE XIII.—*Bleached yarns matched against a series of standard whites.*

Method.		Arizona-Egyptian.				Sea Island.		Sakellaridis.		
		1	2	3	4	5	6	7	8	9
(A)	Set.....	3	3	3	3	3	3	3	3	3
	Standard.....	7	7	7	7	7	7	6	6	6
(B)	Set.....	3	3	3	3	3	3	3	3	3
	Standard.....	6	6	6	6	6	6	4	4	4

In the laboratory tests, the deviations in the numbers were standardized on the basis of the average number of the gray, the bleached, and the mercerized, respectively. When the tensile strength of the gray yarn was compared with the results obtained in the laboratory, yarn from the same bobbins was used in each case. From these bobbins 60 yards instead of 120 yards per skein were used. (See footnote 1, p. 8.)

The tensile strength of 80/2 yarns of each of the nine kinds was taken before and after bleaching with methods (A) and (B). The results of these tests are shown in Table XIV.

TABLE XIV.—*Tensile strength before and after bleaching.*

Sample number.	Gray.			Bleach A.			Bleach B.		
	Num- ber of yarn.	Tensile strength.		Num- ber of yarn.	Tensile strength.		Num- ber of yarn.	Tensile strength.	
		Pounds per skein (60 yards).	Ounces per single thread.		Pounds per skein (60 yards).	Ounces per single thread.		Pounds per skein (60 yards).	Ounces per single thread.
1.....	42.3	37.9	8.7	46.4	31.1	7.0	47.0	34.6	8.3
2.....	42.3	34.8	8.5	46.4	26.7	7.3	47.0	.....	.....
3.....	42.3	36.2	8.2	46.4	28.8	7.1	47.0	33.0	8.4
4.....	42.3	34.3	7.9	46.4	28.5	7.1	47.0	31.0	8.6
5.....	42.3	38.2	9.0	46.4	29.7	6.9	47.0	38.8	8.7
6.....	42.3	35.1	8.4	46.4	27.2	6.7	47.0	28.0	7.0
7.....	42.3	37.7	8.4	46.4	31.7	7.4	47.0	37.0	8.2
8.....	42.3	36.0	8.6	46.4	33.8	8.3	47.0	29.5	8.8
9.....	42.3	32.5	8.2	46.4	28.3	7.8	47.0	34.0	7.9
Average 1-9.....	42.3	35.8	8.4	46.4	29.5	7.3	47.0	33.2	8.2
Average 1-4.....	42.3	35.8	8.3	46.4	28.8	7.1	47.0	32.9	8.4
Average 5-6.....	42.3	36.6	8.7	46.4	28.4	6.8	47.0	33.4	7.9
Average 7-9.....	42.3	35.4	8.4	46.4	31.3	7.8	47.0	33.5	8.3

A comparison of the figures in Table XIV shows that the Arizona-Egyptian cotton was slightly weaker in the gray than the average of all, and that the Sea Island was stronger than the average of all. When bleached according to method (A) the Arizona-Egyptian was also weaker than the average and the Sakellaridis stronger. When bleached according to method (B) the Arizona-Egyptian was the weakest and the Sea Island the strongest. These deviations from the average strength, however, are not greater than the variations found between the several tests on the same yarn. Hence, this table of averages does not indicate a very serious variation in the strength.

DYEING.

Samples of the yarns were bleached according to method (B), but not blued. These samples were dyed pink and blue by the methods given below for direct and basic dyes. The results of these tests indicated no appreciable difference in the dyeing values of the nine cottons tested. The two methods are as follows:

Direct dyes.—The yarns were dyed in a bath containing a 0.1 per cent benzo rhoduline red B, 5 per cent of salt, and a 0.5 per cent soluble oil. The volume of dye bath equaled 25 times the weight of the goods. The goods entered the dye bath cold, and the temperature was raised to the boiling point in 30 minutes. They were boiled 15 minutes and allowed to cool in the bath 15 minutes. The light blue was dyed in the same manner, except that a 0.1 per cent benzo fast blue B N was used instead of the benzo rhoduline red B.

Basic dyes.—The goods were mordanted in a solution containing 0.015 of a gram of tannic acid in each 100 cc. The goods were entered cold; the temperature of the bath was raised to 190° in 45 minutes; it then was allowed to cool over night, rinsed and treated cold for 15 minutes in a bath containing 0.01 of a gram of tartar emetic.

The pinks were dyed in a bath containing 0.05 per cent of rhoduline red B, 0.5 per cent of acetic acid, cooled 30 minutes, then raised to 140° during 30 minutes. The blues were dyed in the same manner as the pink, except that 0.05 per cent of methylene blue B B was used.

MERCERIZING.

Samples of each of the nine kinds of yarns (60/2) were singed and mercerized collectively at one of the mills of New Bedford, Mass., and subsequently tested for their tensile strength and degree of mercerization. The tensile strength and the numbers of the yarn of all nine samples were taken before and after mercerization. The results are shown in Table XV.

TABLE XV.—*Tensile strength before and after mercerization.*

Number of sample.	Gray yarn.			Mercerized yarn.		
	Number of yarn.	Tensile strength.		Number of yarn.	Tensile strength.	
		Pounds per skein (60 yards).	Ounces per single thread.		Pounds per skein (60 yards).	Ounces per single thread.
1.....	31.6	48.5	11.6	33.6	57.5	16.5
2.....	31.6	48.0	10.9	33.6	59.9	16.7
3.....	31.6	49.3	11.7	33.6	56.8	17.2
4.....	31.6	49.9	11.8	33.6	56.9	16.4
5.....	31.6	51.0	-----	33.6	60.4	17.9
6.....	31.6	48.9	11.5	33.6	57.0	18.4
7.....	31.6	51.4	12.1	33.6	59.8	18.3
8.....	31.6	51.5	12.3	33.6	59.4	18.1
9.....	31.6	51.3	12.1	33.6	56.5	17.3
Average 1-9.....	31.6	50.0	11.8	33.6	58.2	17.4
Average 1-4.....	31.6	48.9	11.5	33.6	57.8	16.7
Average 5-6.....	31.6	50.0	-----	33.6	58.7	18.2
Average 7-9.....	31.6	51.4	12.2	33.6	58.6	17.9

It will be noticed in Table XV that the mercerized samples 1-4, inclusive, show a lower breaking strength than samples 5-6 or 7-9.

The yarns were tested for degree of mercerization by dyeing them in 1 per cent benzo purpurin 4B, 10 per cent salt, 1 per cent soluble oil for 30 minutes at 160°, volume of bath equal to 100 times the weight of goods treated. In order to determine the degree of mercerization, samples of mercerized Egyptian yarn were dyed in the same baths after dyeing the samples 1-9. These exhaust skeins furnished a means of measuring the degree of mercerization, for the better mercerized samples of cotton absorb more dyestuff and consequently leave less in the dye bath.

Table XVI represents a set of standards obtained by dyeing mercerized Egyptian yarn with the following percentages of dyestuff salt and soluble oil by method given above, benzo purpurin 4B being used as the dyestuff.

TABLE XVI.—*A set of color standards.*

Standard No.....	1	2	3	4	5	6	7	8	9
Dye per cent.....	5	4.5	4	3.5	3	2.5	2	1.5	1
Salt per cent.....	20	20	20	20	20	20	10	10	10
Soluble oil per cent.....	2	2	2	2	2	2	1	1	1
Standard No.....	10	11	12	13	14	15	16	17	18
Dye per cent.....	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Salt per cent.....	10	10	10	10	10	10	10	10	10
Soluble oil per cent.....	1	1	1	1	1	1	1	1	1
Standard No.....	19	20	21	22	23	24	25	26	27
Dye per cent.....	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01
Salt per cent.....	10	10	10	10	10	10	10	10	10
Soluble oil per cent.....	1	1	1	1	1	1	1	1	1

By matching the samples of yarn dyed in the exhaust baths against the above standards the results shown in Table XVII were obtained.

TABLE XVII.—*Mercerized yarns matched against color standards for degree of mercerization.*

	Arizona-Egyptian.				Sea Island.		Sakellaridis.		
Yarn samples.....	1	2	3	4	5	6	7	8	9
Matched standards.....	17+	17	17+	17	16	17—	16—	14+	15—

From Table XVII it will be seen that the Arizona-Egyptian cotton samples 1-4 gave better results in mercerizing than any of the others, the nearest approach to it being that of sample 6, Sea Island cotton.

These laboratory tests show that after bleaching, dyeing and mercerizing, the Arizona-Egyptian and Sea Island cottons were practically equal to each other and were slightly superior to the Sakellaridis Egyptian in their bleaching and mercerization properties; that they were fully the equal in dyeing properties, possibly ranging slightly in favor of the Sea Island and Sakellaridis in tensile strength.

DIFFICULTIES IN INTRODUCING A NEW VARIETY OF COTTON.

The manufacturer usually secures a contract for goods before they are manufactured, but when offering a fabric or yarn for sale, manufactured from a new kind of cotton, difficulties frequently are met with from the buyer or converter who, when placing a contract or an order for fine goods, specifies the kind of cotton required, that is, American, Egyptian, or Sea Island. In a large number of instances on cloth orders, the warp required is of American cotton and the filling Egyptian, or vice versa. The grade of cotton used is, of course,

at the discretion of the manufacturer, provided he meets the requirements of contract as to the strength and quality. Manufacturers who have experimented with the Arizona-Egyptian cotton have found that it is less wasty than other cottons and that it can be utilized satisfactorily as a substitute for most purposes; but so long as the manufacturer meets his contract, the amount of waste discarded in the manufacturing processes is not primarily of interest to the converter or consumer. In fact, manufacturers are reluctant to change while their business is on a profitable basis. However, on certain classes of goods, mixtures of two different cottons are made to advantage. Because the Arizona-Egyptian is a heavy bodied cotton, it is entirely possible that the entire amount produced can be utilized advantageously if mixed properly with these other cottons in the manufacturing processes. Manufacturers claim that the sooner this cotton comes on the market in large quantities, the easier will it be to place it on a competitive basis with other long-staple cottons of similar qualities.

COMPARATIVE SPINNING TESTS MADE FROM THE CROP OF 1913-14.

Previous to the tests made in the summer of 1915, there were similar tests conducted in the summer of 1914 on cotton of the 1913 crop.¹ These preliminary tests were made on about 35 pounds of each grade of Arizona-Egyptian cotton and were run in comparison with a lap of Sakellaridis Egyptian and a lap of Sea Island cotton which had been run through the pickers in a cotton mill. There was not available a sufficient quantity of Arizona-Egyptian cotton to make these tests conclusive, nor were the Sakellaridis Egyptian nor the Sea Island cotton procured in the raw condition. It was assumed that the laps of the Sakellaridis and the Sea Island cottons had lost their usual amount of waste through the pickers and contained the average amount of waste usually present in cottons of their class when ready to be started into the cards. From this point on, the different lots were run under the same mechanical conditions without change in speeds or settings. The length of staple of the three lots was approximately equal.

The percentages of waste for the five grades of Arizona-Egyptian cotton, based on the net amount of cotton fed to the pickers, were as follows:

	Per cent.
Fancy.....	16.38
Extra.....	16.35
Choice.....	17.44
Standard.....	23.99
Medium.....	24.35

¹ These tests were conducted at the New Bedford Textile School by Mr. Fred Taylor.

The percentages of waste discarded by the cards and combers for the Arizona-Egyptian, Sakellaridis Egyptian, and Sea Island cottons, based on the amount of cotton fed into the cards instead of pickers, were as follows:

Arizona-Egyptian:	Per cent.
Fancy.....	14.15
Extra.....	15.36
Choice.....	16.16
Standard.....	21.48
Medium.....	21.38
Average Arizona-Egyptian.....	17.70
Sea Island.....	19.03
Sakellaridis Egyptian.....	17.54

These tests do not seem to indicate very definitely which variety of cotton would be the best, when judged from the standpoint of percentage of waste discarded in the manufacturing processes.

The average size of the yarn produced from the three lots of cotton was 100's. The average tensile strength for the three lots was as follows:

	Pounds per skein.
Arizona-Egyptian.....	20.02
Sea Island.....	19.06
Sakellaridis Egyptian.....	19.70

There seem to be no conclusions as to the superiority of any variety of cotton that can be satisfactorily drawn from the comparison of the tensile strength of these three lots.

The principal points of interest wherein these preliminary tests coincide with the results of the tests on the crop of 1914-15 are as follows: (1) The total amount of waste discarded in the manufacturing processes of the different grades of Arizona-Egyptian cotton bears some relation to the grades; (2) the tensile strength figures do not indicate definitely that one lot is superior to another.

A comparison of the results of the tests made on cotton of the 1913-14 and 1914-15 seasons shows that there is such a discrepancy in the amount of waste discarded from the same kind of cotton that the results of neither test can be accepted as absolutely conclusive.

SUMMARY.

The relative waste discarded in the manufacturing processes of the four grades of Arizona-Egyptian cotton tested was as follows: Extra, 17.69 per cent; Choice, 18.56 per cent; Standard, 20 per cent; Medium, 20.90 per cent.

These tests show that with respect to grade the four bales of Arizona-Egyptian cotton were proportionately less wasty than the two bales of Sea Island of Georgia, and the two bales of Sea Island were pro-

portionately less wasty than the three bales of Sakellaridis from Alexandria, Egypt.

There was no relation in the price of the different kinds of cotton to the percentages of waste discarded in the manufacturing processes. The reverse condition developed, namely, Arizona-Egyptian cotton was estimated to be lower in commercial value than Sea Island, and Sea Island to be lower than Sakellaridis, when comparing equivalent grades.

There was no significant relationship between the tensile strength of the respective grades of Arizona-Egyptian cotton.

The difference in the tensile strength of yarn made from the three

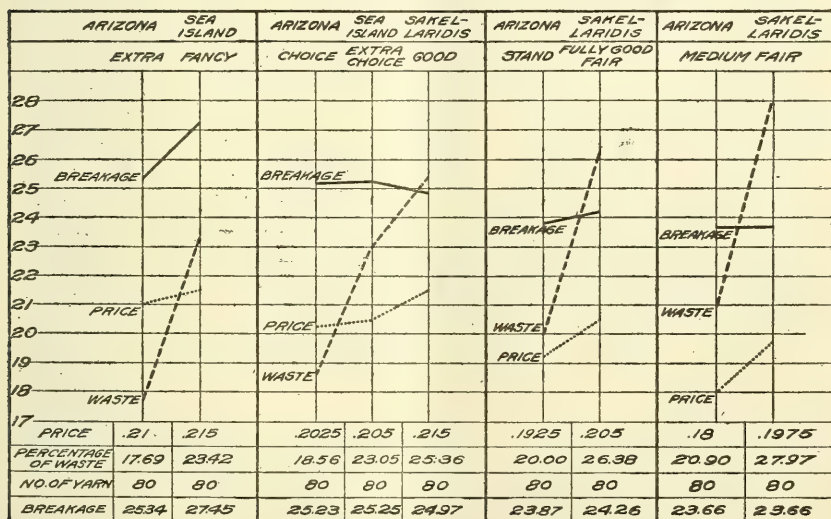


FIG. 2.—Comparison of the prices of raw cotton, waste discarded in the manufacturing processes, and the tensile strength of the yarn in pounds per skein of 120 yards each for Arizona-Egyptian, Sea Island, and Sakellaridis Egyptian cottons.

(The figures at the left indicate the cents per pound for the price, percentage for the waste, and pounds per skein for the breaking strength.)

kinds of cotton was practically negligible. Considerable deviation occurred varying slightly in favor of first one kind and then another, but, as a whole, resulting somewhat in favor of the Sakellaridis Egyptian cotton, with the Sea Island coming second. However, the tensile strength for the highest numbers of yarn was in favor of the Sea Island cotton.

Figure 2 presents graphically the comparative prices of the three kinds of cotton, the percentages of waste of each kind discarded in the manufacturing processes, and the tensile strengths of the yarn made from them. The graph is arranged for comparing the grades that are practically equivalent. The table at the bottom of this graph gives the figures referred to which are taken from previous

tables and placed here for ready reference. The figures on the left-hand margin indicate cents per pound for the price, percentage for the waste, and pounds per skein for the breaking strength. Number 80's yarn was taken for the comparison. The graph shows that there is no significant relationship between the prices of the different cottons and the percentages of waste and tensile strength. It shows that our domestic cottons are equal to, and in most respects superior to, imported cottons. It indicates also the preferences of manufacturers which must be changed in order to introduce satisfactorily any new cotton.

The laboratory test indicated that after bleaching, dyeing, and mercerizing, the Arizona-Egyptian and Sea Island cottons were practically equal to each other and were slightly superior to the Sakellaridis in their bleaching and mercerizing properties; that they were fully equal to each other in dyeing properties; and in tensile strength the advantage was slightly in favor of the Sea Island and Sakellaridis. The finished grey and mercerized yarns were comparatively equal in luster; however, the yellow color was a little more evident in the Arizona-Egyptian than in the Sakellaridis, which in turn was somewhat more yellow than the Sea Island. The difference in color was more apparent between the Arizona and the Sakellaridis than between the Sea Island and Sakellaridis.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO THE SUBJECT.

BUREAU OF PLANT INDUSTRY PUBLICATIONS.

- Bulletin 128, Egyptian Cotton in the Southwestern United States. By T. H. Kearney and W. A. Peterson.
- Bulletin 156, A Study of Diversity in Egyptian Cotton. By O. F. Cook, Argyle McLachlan, and A. M. Meade.
- Bulletin 200, Breeding New Types of Egyptian Cotton. By T. H. Kearney.
- Bulletin 210, Hindi Cotton in Egypt. By O. F. Cook.
- Bulletin 249, The Branching Habits of Egyptian Cotton. By Argyle McLachlan.
- Bulletin 256, Heredity and Cotton Breeding. By O. F. Cook.
- Circular 29, Experiments with Egyptian Cotton in 1908. By T. H. Kearney and W. A. Peterson.
- Circular 66, Cotton Selection on the Farm by the Characters of the Stalks, Leaves, and Bolls. By O. F. Cook.
- Circular 110, Miscellaneous Papers—Preparation of Land for Egyptian Cotton in Salt River Valley, Arizona. By E. W. Hudson. Fibers from Different Pickings of Egyptian Cotton. By T. H. Kearney.
- Circular 111, Durango Cotton in the Imperial Valley. By O. F. Cook.
- Circular 112, Egyptian Cotton as Affected by Soil Variations. By T. H. Kearney.
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- Bulletin 38, Seed Selection of Egyptian Cotton. By T. H. Kearney.
- Bulletin 121, Spinning Tests of Upland Long-Staple Cottons. By Fred Taylor and Wells A. Sherman.
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- Bulletin 233, Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. By B. R. Coad.
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BULLETIN No. 360

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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER

June 17, 1916

MISTLETOE INJURY TO CONIFERS IN THE NORTHWEST.¹

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INTRODUCTION.

It is not generally known that the injury by the mistletoes to coniferous trees in the northwestern United States is such as to assume in many regions the nature of a serious forest problem. The aim of this bulletin is to point out some of the direct and indirect results of this injury. The species of trees most subject to injury are *Larix occidentalis* (western larch), *Pinus ponderosa* (western yellow pine), *Pinus contorta* (lodgepole pine), and *Pseudotsuga taxifolia* (Douglas fir). Each of these trees is attacked by a particular species of mistletoe of the genus *Razoumofskyia* (*Arceuthobium*). With a few exceptions, these species very rarely occur in nature on any other than their common hosts. In the order of the above-named hosts they are *Razoumofskyia laricis* Piper (Pl. I, fig. 1), *R. campylopoda* (Engelm.) Piper (Pl. II, fig. 2), *R. americana* (Nutt.) Kuntze (Pl. I, fig. 2), and *R. douglasii* (Engelm.) Kuntze (Pl. II, fig. 1).

¹ Thanks are due Mr. E. E. Hubert for assistance in the preparation of the graphs and a number of the other illustrations used in this bulletin.

GENERAL NATURE OF THE MISTLETOE INJURY.

The general nature of the injury to forest growth by these parasites principally consists sooner or later in a localization and gradual reduction of the assimilatory leaf surface of the host. As will be shown, this is caused by various burl and broom formations on the trunks and branches. The reduction of the leaf surface causes a falling off of the annual increment. During the progress of a study on the larch mistletoe in the Whitman National Forest, Oreg., in the summer of 1913, many data on the retardation of growth of its host by this parasite were assembled. More recently, in the lodgepole and yellow pine belt of eastern Washington and northern Idaho, the study was continued on these species, and at frequent intervals on the larch and Douglas fir in the Missoula region of Montana. The method of investigation was as follows: Borings from heavily infected (burled and broomed) and uninfected trees were taken with a Mattison increment borer at $4\frac{1}{2}$ feet from the ground, at which point the trees were calipered. With practice the eccentricity of growth due to slope, unequal crown development, injuries, etc., may be very skillfully judged, so that it is possible to strike the pith of trees within the range of the borer with a fair degree of accuracy. In order to determine as nearly as possible the average radius, in the more doubtful cases three borings were taken. On steep slopes the eccentricity of trees may be more accurately judged than on flat land, through the knowledge that more rapid growth takes place on the downhill side of the tree. Height was computed with the Klaussner height measurer. Trees of the same species were selected as near as possible from the same type of stand and of the same general age class and the same soil conditions. Only dominant trees free from serious wounds and other possible causes of deterioration were recorded. Finding that the effects of the mistletoe on the increment of the host could be read from the last 40 years' growth of the age classes and conditions of infection selected, Table I was prepared.

TABLE I.—*The retardation of growth of forest trees caused by mistletoe, for 40 years, 1874 to 1913, inclusive.*

Host and condition.	Basis (num- ber of trees).	Average.			
		Age class.	Height.	Diameter breast high.	Total annual growth.
		<i>Years.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Inches.</i>
Pinus contorta:					
Infected.....	50	65	35.2	6.3	0.93
Uninfected.....	50	60	48.5	7.8	2.93
Pinus ponderosa:					
Infected.....	50	100	49.5	18.2	1.54
Uninfected.....	50	100	77.2	22.2	5.33
Larix occidentalis:					
Infected.....	80	144	63.0	11.5	1.28
Uninfected.....	80	144	115.0	19.5	2.154
Pseudotsuga taxifolia:					
Infected.....	40	97	62.0	17.3	2.175
Uninfected.....	40	97	73.0	22.2	3.28

The results in Table I, although based on a relatively small number of trees, prove quite conclusively the effects of mistletoe on the growth of its host. They are graphically shown by the accompanying series of illustrations (figs. 1 to 4).

A glance at these graphs shows that although there is considerable fluctuation in growth, the line of the uninfected rarely falls below that of the infected trees.

These results are not at all surprising when the nature of mistletoe injury is thoroughly appreciated. In a heavily infected region, where all species and ages are more or less involved, dead, dying, or

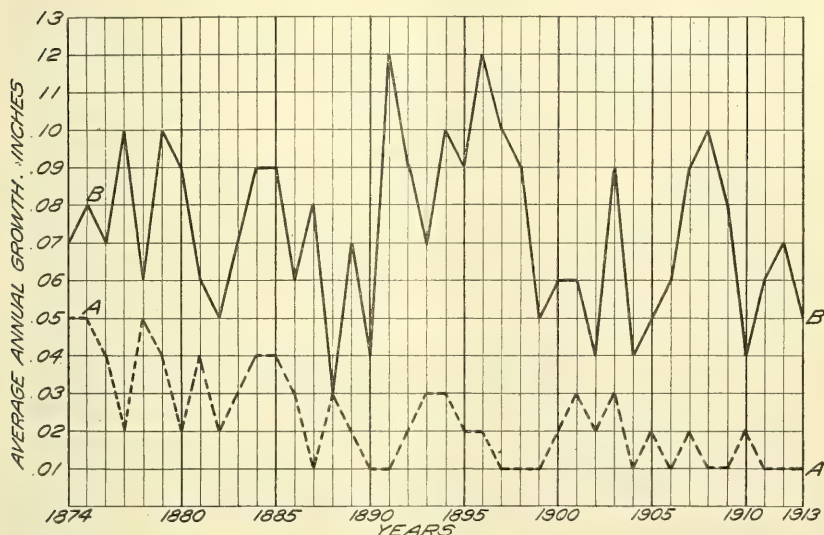


FIG. 1.—Graphs showing the average annual growth (in inches) for 40 years (1874 to 1913, inclusive) of 50 trees of lodgepole pine heavily infected with mistletoe, compared with 50 uninfected trees of the same species for the same period. *A*, Heavily infected trees: Average-age class, 65 years; average height, 35.2 feet; average diameter, breast high, 6.3 inches. *B*, Uninfected trees: Average-age class, 60 years; average height, 48.5 feet; average diameter, breast high, 7.8 inches.

weakened mistletoe trees, hastened in their decline by the inroads of fungi and insects, are a common sight. If these trees are carefully examined with respect to the average possible growth for the region, it will be found, as Table I shows, that most of them have died or have become irrevocably weakened or suppressed at a time when rapid or a normal growth should be taking place. This has been found to be true in all regions visited in the Northwest where excessive mistletoe infection is common. Infected trees of immature years, pole size and younger, may linger along indefinitely if secondary agents do not appear and may reach an advanced age, but may not attain a merchantable size. Heavily infected and, as a result of this

infection, badly stunted yellow pine, larch, Douglas fir, and lodgepole pine growing in the open and on otherwise good sites often measure less than 6 inches at the stump, but show ages ranging from 100 to 200 years or more. Young seedlings, if not killed outright within a comparatively short time after infection, usually show a

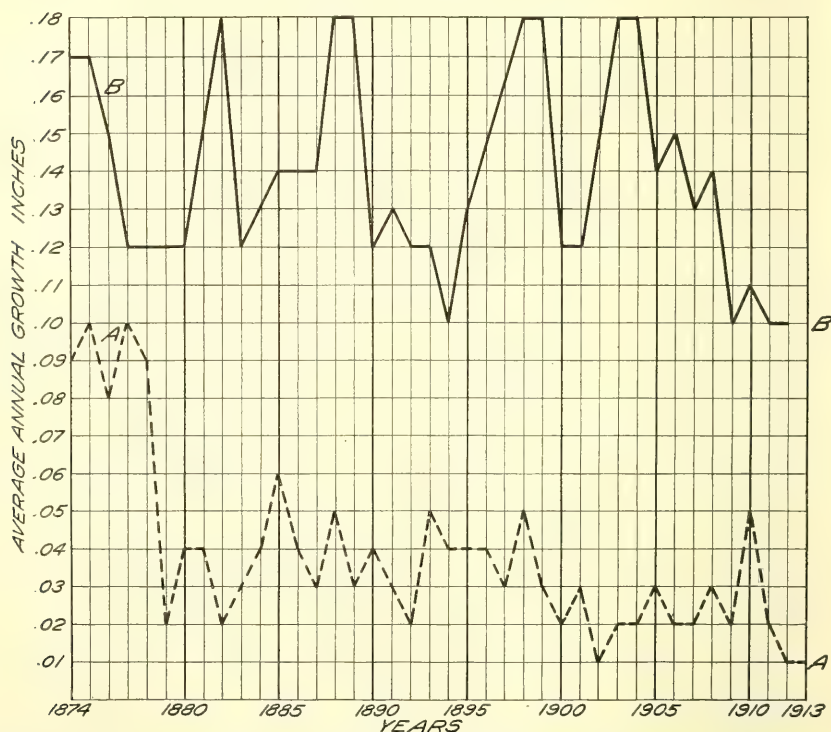


FIG. 2.—Graphs showing the average annual growth (in inches) for 40 years (1874 to 1913, inclusive) of 50 trees of yellow pine heavily infected with mistletoe, compared with 50 uninfected trees of the same species for the same period. A, heavily infected trees: Average-age class, 100 years; average height, 49.5 feet; average diameter, breast high, 18.2 inches. B, Uninfected trees: Average-age class, 100 years; average height, 77.2 feet; average diameter, breast high, 22 inches.

marked falling off of the foliar surface of the parts uninfected and finally succumb to the attack (fig. 5). Very frequently young infected seedlings develop into ball-like brooms.

Table II shows the youngest age class of five hosts at which mistletoe infection has been found to occur and the locality where the observations were made.

TABLE II.—*The youngest age class of mistletoe infection on five different hosts.*

Host.	Youngest age at which infection is known to occur.	Locality where observations were made.
<i>Pseudotsuga taxifolia</i>	4	Clark Fork Valley, Mont. ¹
Do.....	7	Blue Mountains, Oreg.
<i>Larix occidentalis</i>	5	Priest River Valley, Idaho.
Do.....	4	Blue Mountains, Oreg.
Do.....	3	Missoula, Mont.
Do.....	7	Sullivan Lake, Wash.
<i>Pinus contorta</i>	5	Spokane River, Wash.
Do.....	3	Blue Mountains, Oreg.
Do.....	6	Coeur d'Alene, Idaho.
<i>Pinus ponderosa</i>	5	Spokane River, Wash.
Do.....	3	Blue Mountains, Oreg.
Do.....	4	Coeur d'Alene, Idaho.
<i>Tsuga heterophylla</i>	8	Clearwater River, Idaho.

¹ Valleys of the so-called Bitterroot and Missoula Rivers.

There is no reason why a seedling should not become infected during its first year if seeds should happen to be favorably located upon it. Seeds falling at the base of terminal buds of yellow-pine branches have been known to effect an entrance in the succeeding

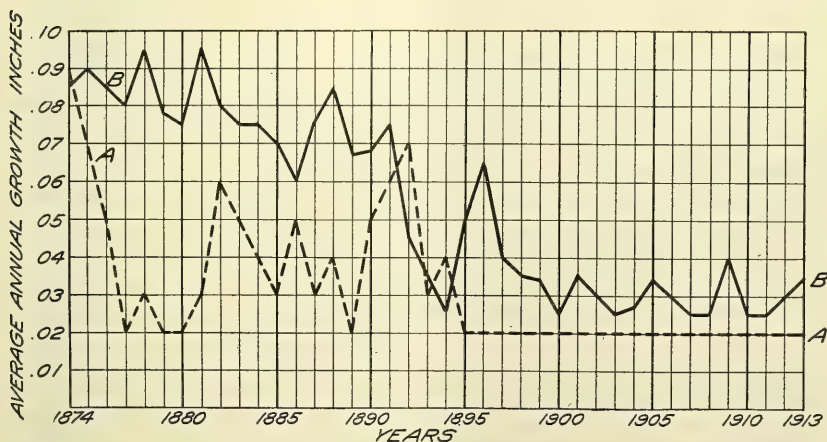


FIG. 3.—Graphs showing the average annual growth (in inches) for 40 years (1874 to 1913, inclusive) of 80 trees of western larch heavily infected with mistletoe, compared with 80 uninfected trees of the same species for the same period. A, Heavily infected trees: Average-age class, 144 years; average height, 63 feet; average diameter, breast high, 11.5 inches. B, Uninfected trees: Average-age class, 144 years; average height, 115 feet; average diameter, breast high, 19.5 inches.

season's growth within the year. All infections of firs and spruces have been found on trees ranging from 50 to 150 years. They occurred principally on the branches, resulting in large brooms, so that nothing could be determined as to the probable age of the hosts when infection took place.

No evidence is at hand to show that the primary sinker of these parasites can penetrate other than the more tender epidermis of young parts of the host. Germinating mistletoe seeds located on the smooth bark of the Douglas fir or on the irregularities of older stems of yellow pine or larch have never been observed, even after a protracted contact of the disk of the hypocotyl with the surface of the branch, to penetrate the bark. Removing the exhausted hypocotyl and carefully examining the point where the disk was attached, a barely perceptible pit or indentation is sometimes visible,

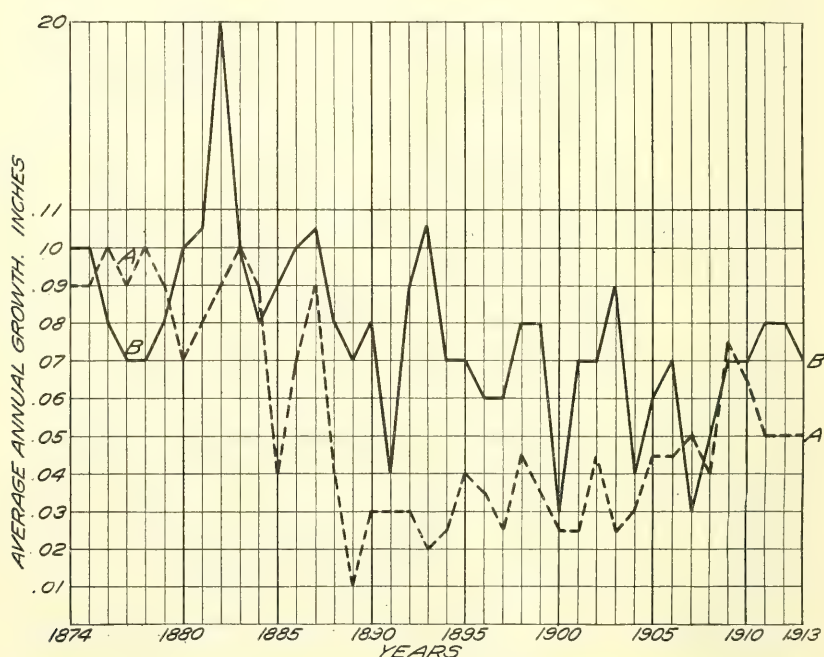


FIG. 4.—Graphs showing the average annual growth (in inches) for 40 years (1874 to 1913, inclusive) of 40 trees of Douglas fir heavily infected with mistletoe, compared with 40 uninfected trees of the same species for the same period. A, Heavily infected trees: Average-age class, 97 years; average height, 62 feet; average diameter, breast high, 17.3 inches. B, Uninfected trees: Average-age class, 97 years; average height, 73 feet; average diameter, breast high, 22.2 inches.

possibly indicating the presence of a solvent, which, however, is ineffective upon more mature bark. There is as yet no proof to support the theory of the presence of a digestive substance which enables the sinker to penetrate the bark more readily. If this were true, infection could possibly occur on older tissues, provided they were not too thick and the food supply in the seed did not become exhausted. As it is, mechanical force, supported by the nonmovable position of the seed, and irregularities of the stems, such as leaf scales, exits of leaf traces, and leaf sheaths, particularly at

the nodes and the basal scales of the terminal buds, are the chief factors in the penetration of the primary root.

The occurrence of mistletoe plants on the thick-barked branches of old trees or on the main trunk are the result of earlier infection, when the bark was thinner. What appears to be a recent infection on the older parts of trees is often merely a retarded or suppressed condition of an earlier infection which has expended most of its energy in the production of a sub-cortical stroma and later breaks through the bark. Periods of suppression and dominance are frequently noticeable in all mistletoes, a condition noted to be in several instances directly referable to the state of vigor of the host. An excessive flow of resin sometimes appears in the second and third year of the life of a new infection on larch and yellow pine, which, if not fatal to the young plants, may seriously retard their growth for years. Until infection by actual inoculation, using natural methods, is attained, all statements of the ability of the parasite to effect an entrance in old-barked branches or trunks can not be accepted and must be considered faulty observation. The

writer has never succeeded in causing the infection of branches at any point older than four years. The ease of infection is found to be more or less in proportion to the decrease in age of the branches tested. This was proved in the case of yellow pine by inserting seeds at regular intervals in the axils of the leaf sheaths of young branches, from the terminal bud to the tenth internode. The results of this experiment are shown in Table III.



FIG. 5.—Four-year-old yellow-pine seedlings killed by mistletoe. Note the hypertrophy of the stem at the point of infection and the shortening of the needles. The two seedlings on the right were killed principally by having the wood and cambium in the swelling infiltrated with pitch. The parasite killed the seedling on the left by invading the terminal shoot.

TABLE III.—*Inoculation of Razoumofskya campylopoda on Pinus ponderosa, made in November, 1911.*

[x=Inoculation effective; 0=inoculation not effective.]

Age of part of branch tested.	Seeds sown on each internode.	Results in November, 1914, on branch—				
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Season's growth.....	10	x	x	x	0	0
1 year.....	10	0	0	x	x	0
2 years.....	10	0	0	0	0	x
3 years.....	10	0	0	0	0	0
4 years.....	10	0	0	0	0	0
5 years.....	10	0	0	0	0	0
6 years.....	10	0	0	0	0	0
7 years.....	10	0	0	0	0	0
8 years.....	10	0	0	0	0	0
9 years.....	10	0	0	0	0	0
10 years.....	10	0	0	0	0	0

A study of Table III shows that the branches were infected in three out of the five test cases on the youngest and last internode on which the seeds were placed. Infection occurred on two of the five tested branches on that part 1 year old at the time of sowing, one infection only being on the 2-year-old portion. Infection did not take place on the older parts of the branches. A tree never becomes too old for infection to occur on its youngest branches. Suppressed trees may escape, owing to the fact that slowness of growth and more rapid formation of thick bark lessens the chance of infection; also shortness of twig growth gives less opportunity. The demand for a fair amount of light is also a factor in such a case, not, however, for the stages of germination and penetration of the primary root, but for the subsequent development of the aerial parts. Mature trees becoming infected on tender branches may not suffer any appreciable injury, but in time the decline of the tree is surely hastened, since the gradually increasing hypertrophy of the branches, the breakages, and the thinning out of the foliage of the tree as a whole cause it to be greatly weakened. Almost always the result of a heavy infection on the trunk and branches of some conifers is the death of the upper portion of the crown,¹ causing staghead (fig. 6),

¹ The dying back of the crown of trees, commonly known as spiketop, or staghead, is attributed to various causes; as many, in fact, as the varied conditions under which trees grow. One of the most common theories is that on opening up a stand the admission of light to the trunk and lower crown deflects the transpiration current to the older branch orders or, as with some species, promotes the formation of a secondary crown on the main trunk. This stimulated foliar activity below reduces the water supply at the top of the crown; consequently the topmost branches die back. This is exactly what happens in the case of mistletoes. The extra crown development below, by brooming, starves out the crown above, resulting in its death. Münch (Silva, December, 1911, pp. 415-416) claims to have found a parasitic Ascomycete which causes staghead in the oak of Europe by attacking the bark and outer wood of the main shoots. The writer has found a wood-destroying fungus which attacks the upper crown branches of the chestnut in southern Indiana and causes their death. The "pencil rot," which seems to be frequently the cause of staghead in the western red cedar, is another example of fungi attacking the crown of trees. Lightning is a common cause of staghead; also injury by insects.

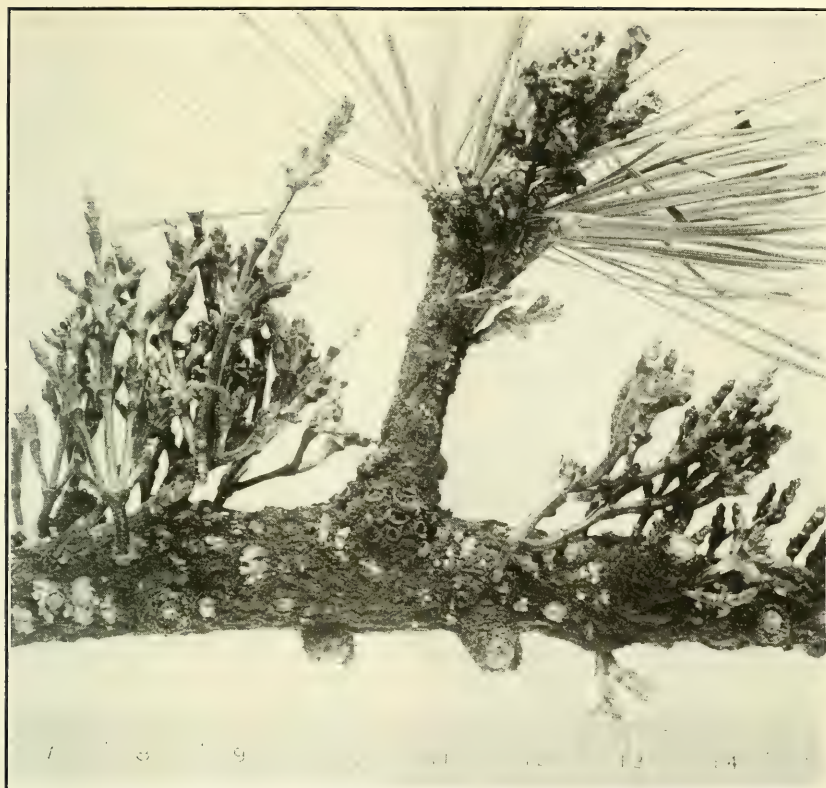


FIG. 1.—BRANCH OF *LARIX OCCIDENTALIS* INFECTED WITH *RAZOUMOFSKYA LARICIS*.
The staminate and pistillate plants are in close juxtaposition, the former at the end of the twig.

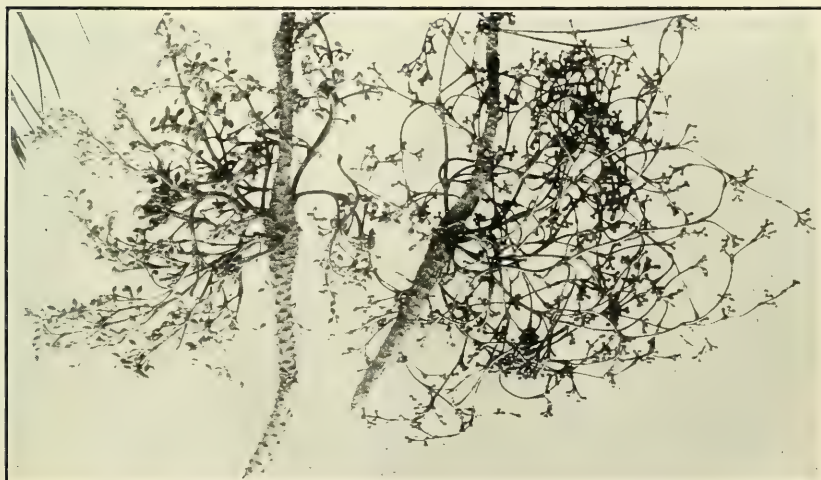


FIG. 2.—*RAZOUMOFSKYA AMERICANA* ON *PINUS CONTORTA*.
Staminate and pistillate plants; long trailing form.



FIG. 1.—*RAZOUMOFSKYA DOUGLASII* ON *PSEUDOTSUGA TAXIFOLIA*.
Staminate plants, slightly less than natural size.



FIG. 2.—*RAZOUMOFSKYA CAMPYLOPODA* ON *PINUS PONDEROSA*.
The staminate and pistillate plants are growing close together on the same branch, a very common condition for all species, but not generally known.



FIG. 1.—AN OPEN STAND OF YELLOW PINE HEAVILY INFECTED WITH RAZOUMOFSKYA CAMPYLOPODA.

Note that some of the trees are dead and that others have very thin foliage. The structure of the dead brooms is plainly shown. Some of the trees bear burls on the main trunk. The young growth is seriously infected with mistletoe.



FIG. 2.—A HEAVY GENERAL INFECTION OF A 15-YEAR-OLD YELLOW PINE BY RAZOUMOFSKYA CAMPYLOPODA, RESULTING IN A DISTORTED AND OPEN CONDITION OF THE CROWN WITHOUT PRONOUNCED BROOMING.

The natural excurrent growth of the main trunk is entirely changed.



FIG. 1.—NEEDLES OF DOUGLAS FIR FROM A NORMAL BRANCH (AT THE RIGHT) AND OF A MISTLETOE BROOM ON THE SAME TREE, SHOWING THE DIFFERENCE IN SIZE.



FIG. 2.—YELLOW PINE AT THE HEAD OF A CANYON, SHOWING MISTLETOE INFECTION.

Note that the heaviest infection occurs on the immediate edge of the canyon and that the intensity of the infection decreases as the distance from the brow of the canyon increases; also that the upper crowns of the infected trees are becoming very thin.

or in some cases the entire tree may succumb (fig. 7 and Pl. III, fig. 1.) In many parts of the Whitman National Forest, wherever the heaviest infection of yellow pine occurs the percentage of dead or spiketopped trees reaches a comparatively high figure.

In a report to Supervisor Ireland, Ranger Smith, in referring to the seriousness of the infection of yellow pine in the vicinity of Susanville, Whitman National Forest, states that since 1907, the year in which the mistletoe damage in the region first received attention, the infection

of all age classes has been growing worse, probably 40 per cent of the stand now being infected. Of the more mature stand, approximately twice as many trees near the station as were noted in 1907 have since died. Ranger Smith further states that for a most pronounced general infection of all species the drainage basin of the South Burnt River particularly illustrates the devastating effects of mistletoes. "Almost every yellow pine from seedlings up and Douglas fir above sapling size is heavily infected and most of the mature timber shows great retardation of growth and is now adding little or no increment. This infection covers a large part of the best yellow-pine sites in the yellow-pine belt of this watershed." This region was not visited by the writer, but to judge from studies in other parts of the same forest Ranger Smith's observations are undoubtedly correct.

In order to determine the relative amounts of different species cut as snags on the W. H. Eccles Lumber Co. sale (Whitman Na-

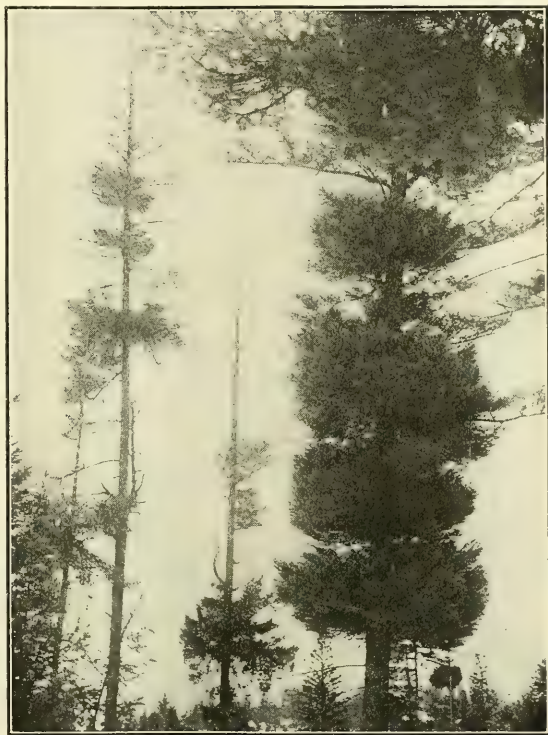


FIG. 6.—Douglas fir, showing the death of the upper portion of the crown caused by *Razoumofskyia douglasii*. The tree to the right with the series of immense brooms also has a dead top. A large broom had split off from the trunk of the tree on the left. All the young growth in the vicinity of these trees is seriously infected.

tional Forest), the following figures were assembled by Mr. T. J. Starker, covering a period of 28 days of cutting:

Western larch	556
Western yellow pine	1, 221
Douglas fir	422
Total	2, 199

It must not be assumed that the death of these trees resulted from mistletoe. It is doubtful whether the death of even a small



FIG. 7.—Douglas fir killed by mistletoe. Note the total absence of normal branches. The structure of the brooms is here plainly shown. Note the straight trunk of the larch in the background. It is uninfected by mistletoe and still retains its original branches.

percentage of them, with the exception of the larch, can be so referred. A more conservative statement would be that mistletoe had a large share in their death by causing spiketop, the brooming of branches, and the formation of burls on the trunk. These are common forms of mistletoe injury for all three species in this region and lead up to serious insect infestation, of which more is said later. That mistletoes are capable of actually causing the death of their hosts is first shown by their effects on young growth from three to eight years old. In a heavily infected but very open stand of yellow pine on the bench lands of the Spokane River, Wash. (Pl. III, fig. 1), an attempt was made to ascertain the amount of injury resulting to the seedlings of an aver-

age sample acre, which included in its area nine semimature and heavily infected trees in all stages of suppression. The acre was divided into plats and all young growth counted and examined as to infection and the condition of the infection. The number of seedlings and small growth below 8 feet in height totaled 480, which is an excellent reproduction for this region. Just a little more than half of this number, or 245, were found to be infected, representing every possible type of infection on stem and branch. It is not to be expected that these seedlings would ever grow up to form merchant-

able trees. Considering the severity of the infection, they could not be expected to attain near the size of their parents shown in Plate III, figure 1, and from which they received the mistletoe. Of the 245 infected seedlings, 49 were dead. An examination of the root system of each seedling showed it to be well developed. In the absence of any other deteriorating influence except an occasional needle infested by *Chionaspis pinifolia* Fitch, the death of these seedlings must be ascribed to the luxuriant growth of mistletoe which they had supported (fig. 5). In most cases the tufts of mistletoe had fallen away. The bark of the large fusiform swellings was usually ruptured and both the wood and bast tissues were so heavily infiltrated with pitch that the passage of food materials between the crown and the roots was wholly impossible, resulting in death. In this respect there is a parallel between this type of mistletoe injury to seedlings and that resulting from the perennial mycelium of some caulicolous *Peridermiums*.

A further study of the large trees shown in Plate III, figure 1, is illuminating. Two of them, the right and the left in the figure, are dead. Scarcely a single normal branch is to be seen, but instead are numerous large gnarled and distorted brooms. These trees measured on an average 9.3 inches in diameter at 4½ feet from the ground, and increment borings showed the age of each to be 190 years. This is far below the diameter of normal trees of the same age for the region. A careful search for secondary causes of injury resulted negatively. The trees were absolutely sound. Lightning injury, which sometimes causes spiketop in yellow pine and other conifers and which sometimes is erroneously attributed to mistletoe, was not present. With the evidence in hand, it is safe to state that the trees



FIG. 8.—A group of Douglas firs with their entire lower crowns developed into brooms by *Razoumofskyia douglasii*. Note the sparse foliage of the upper crowns and the young brooms in the tree on the right, showing how the parasite travels upward. The branches between the brooms have died from lack of nourishment.

were killed by the parasite. The other trees in the figure show various stages of suppression and an abnormal thinness of foliage. The tree on the extreme right shows midway on its trunk a typical mistletoe trunk burl.

It is often disputed that mistletoe is a cause of spiketop or that it is totally unknown for some species. The first and heaviest seat of infection in nearly all trees of economic importance is in the lower part of the crown (figs. 6 and 8). This is not necessarily a result of the seeds of the parasite falling first on the lower branches, but is rather the result of the fact that the main shoot continues for a time to grow in height, and the crown may attain its normal height before the effects of the parasite become dominant. The mistletoe spreads upward from the lowermost branches, with the result that the more recently formed branches are continually being infected. That these infections may not cause a brooming of the branches in the beginning is abundantly shown by the entire absence of any brooming on young infected branches of several host species. This, however, is only the first stage in the hypertrophy of the branch. After the lapse of several years, typical brooms are formed. With the increasing hypertrophy of the lower portion of the crown, food materials are more and more appropriated at this point. The result is a drain on the resources of the entire tree to support the brooms. Materials traveling upward from the roots are likewise utilized by the broomed branches, with the result that the upper portion of the crown starves and in cases of severe infection finally dies (figs. 5, 6, 7, and 8). Spiketop is an almost universal condition in heavily infected larch. The tendency to form spiketop in this species, however, is greatly augmented by the brittleness of its branches. Douglas fir probably comes next in order of frequency of dead tops resulting from the growth of mistletoes. The condition is common for yellow pine in all regions where observations have been made by the writer and is reported to be of frequent occurrence by correspondents in Utah and Wyoming. Lowland and mountain hemlocks, when heavily infected, quite commonly exhibit dead tops. An unusual case of heavy infection of the former species was studied in the St. Joe National Forest. Practically every tree in the entire stand was dead in the top (fig. 9). Lodgepole pine is less affected in this manner than any other conifer so far studied by the writer except spruce and fir. The last-named species are so seldom infected, however, that they would not enter into the discussion.

There can be little doubt that spiketop is very often the result of heavy mistletoe infection, but varies in degree for the several hosts. This condition is of importance, since the proportion of snags in the stand is thereby increased, which may promote injury by fungi and insects; it also increases danger from lightning fires.

With the conclusion of this general statement of mistletoe injury a more detailed discussion of the various types of infection will now be taken up.

RESULT OF INFECTION ON THE BRANCHES.

One of the first effects of infection, either of stem or branch, is the formation of a fusiform swelling (fig. 10). Sometimes this swelling is very pronounced and may resemble the enlargements caused by some species of *Peridermium* (fig. 11). The swelling is the first stage of the future hypertrophy commonly known as witches'-brooms. The absence of any pronounced brooming from early infections has led some observers to the conclusion that brooms are never produced on some conifers. Any change from the normal branching is here considered a broom. Still it is not necessary to draw such sharp lines, as the brooms produced by all mistletoes of the genus in question are quite typical. It may require several years for the broom to form. If young trees are generally infected they

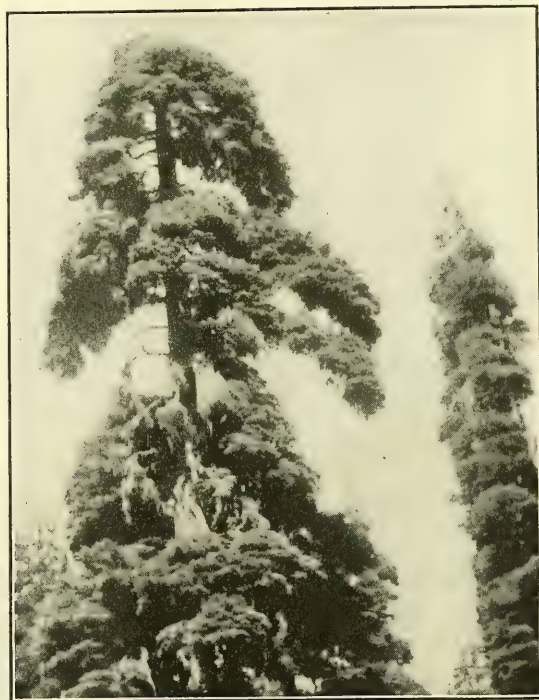


FIG. 9.—Western hemlock (*Tsuga heterophylla*) infected by *Razoumofskyia tsugensis*. These trees do not possess a single normal branch. All are broomed. The trees in the background are spike topped. The tree in the foreground has had its growth in height arrested by an immense terminal broom.

sometimes assume an open, ragged appearance, which to the casual observer would not be considered a broom (Pl. III, fig. 2). Nevertheless, the tree is no longer excurrent. A similar condition is sometimes noted in more mature larches, where the infection is so generally distributed throughout the entire crown that no typical brooms are produced for years. Heavily infected branches of old trees of all species are seldom without brooming of some kind, and in most cases typical brooms are formed. The mistletoe plant may die out entirely on very old brooms, especially those of yellow pine

(fig. 12), but the stimulus to abnormal branching may continue. Brooms are formed on all hosts attacked by this genus of mistletoe.



FIG. 10.—Young, first infections of *Razoumofskyia campylopoda* on western yellow pine (*Pinus ponderosa*).

Those of the yellow pine, owing to their loosely branched condition (fig. 12), are sometimes not as conspicuous as those produced on Douglas fir (figs. 6, 7, and 13), larch (fig. 14), hemlock (fig. 9), or lodgepole pine.

In all the regions where the yellow-pine mistletoe has been observed in the States of Washington, Oregon, Idaho, Montana, and South Dakota, brooming is a common result of the growth of the parasite on this tree. Correspondents in Wyoming, Utah, and Colorado report that old infected trees are seldom without them. MacDougal (8)¹ refers to the excessive brooming of yellow pine by mistletoe in the Southwest. Meinecke (10) refers to the very conspicuous brooms on Jeffrey pine, sugar pine, yellow pine, lodgepole pine, and Douglas fir.

The old brooms of the Douglas fir, because of the long, trailing, willowlike branches of the lower portion of the broom, are more con-

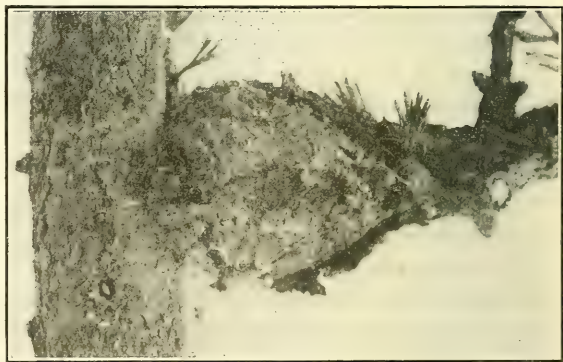


FIG. 11.—A larch branch, showing the result of a first infection at its base by *Razoumofskyia laricis*. This is the beginning of a burl at this point, which will spread to the main trunk.

spicuous than those of other conifers (fig. 13). They sometimes attain an immense size, often including the entire crown (fig. 6). In

¹ Reference is made by number to "Literature cited," p. 39.

most cases brooms are initiated on the Douglas fir soon after infection. Young seedlings frequently die in the top, owing to the formation of a lateral broom midway on the stem. In the heavily infected regions of Montana, especially in the Clark Fork (Bitterroot and Missoula Rivers) drainage, brooming of the Douglas fir is so universal and of such extent that scarcely a single infected tree is free from brooms of some type (figs. 6 and 7). The structure of these brooms is very plainly shown if the tree succumbs to the parasite, as it often does (fig. 7). The formation of brooms invariably results from mistletoe infection on the western larch. They may be situated on any part of the branch or at its base (fig. 14). In the latter case the entire branch eventually dies or is broken off by the wind, and its place is usually taken by a series of short, scrubby secondary branches forming a trunk broom. This broom eventually dies, leaving a large knotty burl of serious consequence not only to the life of the



FIG. 12.—Typical broom on yellow pine caused by *Razoumofskyia campylopoda*. Note that the end of the branch is dead.

tree but greatly decreasing its value for lumber. Excessive brooming is a common feature wherever infected larch occurs and is the chief cause of injury to the species. In some localities in the Blue Mountains of Oregon and parts of Idaho and Montana, where this mistletoe is common, a normally formed larch is seldom found. Instead of the symmetrical, conical crown so characteristic of the normal tree, the crown develops under the influence of the parasite into a denuded spike, bearing only a few ragged branches. When it is recalled that practically every larch in these regions, from pole size up, is more or less infected and seldom attains a normal size, in many cases being killed outright, some notion may be had of the seriousness of the effects of the parasite on its host.

The brooming of the branches of the lodgepole pine by mistletoe is as characteristic as for the other hosts mentioned. Frequently the entire tree is involved, but more often only the lower branches. A few instances have been noted where the parasite hung in long festoons from the several infected branches

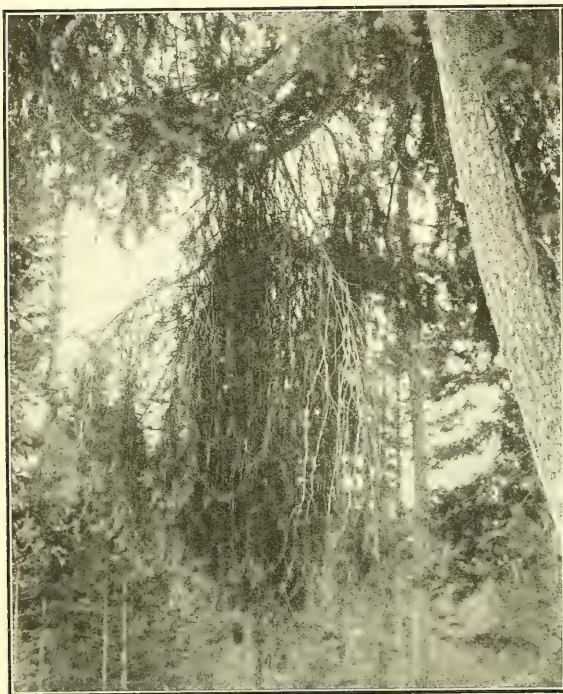


FIG. 13.—Typical broom of the weeping-willow type on Douglas fir caused by *Razoumofskya douglasii*. Note the long, flowing branches. Sometimes these branches are 8 to 10 feet long.

without any particular hypertrophy of the branch as a whole. This condition is more apt to occur in dense stands. Observations by the writer on *Picea engelmanni*, *P. mariana*, *Abies grandis*, *A. lasiocarpa*, *A. concolor*, *A. magnifica*, *Tsuga heterophylla*, *T. mertensiana*, *Pinus monticola*, *P. albicaulis*, *P. flexilis*, *P. attenuata*, and other conifers show that brooming of the branches is a common phenomenon attending mistletoe infection of these species.

The weight of these brooms on many conifers is frequently sufficient under stress of winds and rain to cause the branches to split from the trunk, or to break farther out if the brooms are located far out from the trunk. This very commonly occurs in the case of



FIG. 14.—Typical brooms of old infections on western larch caused by *Razoumofskya laricis*. Very few of the original branches remain, and they are heavily broomed and covered with lichens. The old branches are replaced by short scrubby secondary branches. Note that two of the original branches still remain, but are dead.

yellow pine and Douglas fir (fig. 15) and is the rule for larch. The stunting effect of these brooms on the trees as a whole was in one instance very interestingly shown by the fact that a middle-aged Douglas fir increased the radial dimensions of its annual rings after the removal by the wind of an immense broom located midway on the trunk. The weight of the brooms on some conifers is very often greatly increased by the accumulation of dead needles, lichens, etc. (fig. 14). When loaded with snow or saturated with moisture the brooms are more easily broken off by high winds. The ground around the base of heavily infected larches is very frequently littered with brooms broken off in this manner, often insuring the death of the tree in case of ground fires. During the early part of October, 1914, an unusually heavy fall of soft snow occurred locally over a small area around Missoula, Mont. The snow accumulated in such quantities on the mistletoe brooms of the larches and Douglas firs throughout the area that the ground around the more heavily infected trees was piled high with fallen brooms.

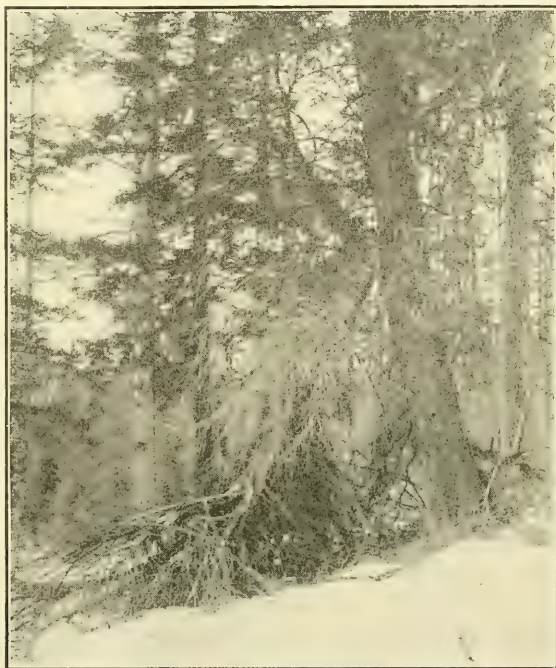


FIG. 15.—Fallen brooms split from the trunk of a Douglas fir and piled about the base of the tree—a serious fire menace.

The foliage of old and mature mistletoe brooms is usually not as long lived as that of normal branches of uninfected trees. This is not true in the case of young well-nourished brooms. It has been observed to any extent only in old brooms which have begun to tax the food supply of the tree or the branch on which they are located. In the course of one year it was determined that 655 more needles fell from a small but mature broom on a Douglas fir than from a normal branch of a neighboring uninfected tree of the same species. The number of needles falling from the broom totaled

976, from the branch 321. On very old brooms of the western larch it is often noticed that the needles begin to turn yellow some time before those on the branches of uninfected trees. Exactly the reverse may occur in the case of recently formed brooms, owing to the larger amount of newly stored food materials in the swelling on the main branch and the branches of the brooms. That the broom may be the cause of a great localization of food substances is indicated by the fact that in heavily infected Douglas fir and larch the last part of the tree to succumb is usually the smaller and younger brooms of the tree. Frequently trees of these species are noticed with only a single small broom living, the rest of the branches being apparently dead; likewise the old and exhausted brooms. The increase in the number of needles on the broom due to the multiplication of its branches is usually at the expense of the needle development on the normal parts of the tree. For this reason an excess of food materials for the tree as a whole does not take place. The foliage beyond the broom becomes thin and, in most cases, the end of the branch dies (figs. 12 and 14). The food materials are entirely stored and appropriated by the broom itself. The phenomenon is analogous to the formation of spiketop of the main trunk.

That brooms do not always necessarily mean an increase in foliar surface for the host, since we have seen that parts of the branches not supporting brooms frequently die, is shown by a comparison of the needles of old brooms with those of normal branches either of the same tree or of uninfected trees. Such a study was made in the case of the Douglas fir. It was found that the needles of the brooms on the trees studied were uniformly a little less than one-half as long as the leaves of the normal branches (Pl. IV, fig. 1). Neither were they as thick or as broad. By compensation it would be possible to determine approximately the actual foliar surface of a given broom and compare it with that of a given normal branch of the same whorl and of the same age. This difference in the size of the needles was found to hold good only in the case of old, mature brooms of trees which were beginning to be suppressed. Young brooms, especially on young trees from 10 to 20 years old, often have abnormally long needles on the still upright branches, but this condition is not long maintained. Soon these branches begin to droop, the broom becomes denser, the needles disappear from the center outward, and they are often sparingly distributed along the stems but more densely assembled on the last few years' growth (fig. 13). With continued suppression of the Douglas fir and exhaustion of the broom, a new type of branching often appears. The long trailing, weeping-willow-like branches cease to elongate and the cortical stroma of the parasite is enabled to catch up with the terminal bud and kill it. The branch

ceases to grow in length and instead forms abnormally abundant lateral branches. The terminal buds of these are likewise overtaken by the parasite, resulting in additional lateral branches, and so on, until a type of dichotomous branching results. This is more noticeable in the compact type of broom than in the long, trailing type, but is quite common in both, especially on exposed and wind-swept areas.

A very interesting hypertrophy of the foliage spurs is often shown by the brooms of the larch. The spurs are frequently abnormally large and may be four or five times as long as those of normal branches (fig. 16). On such spurs the needles are usually shorter and sparingly clustered. Eventually the parasite enters the spur and kills it. Not infrequently a mistletoe plant is found growing out at the apex of the spur or from its side, causing great distortion and the total disappearance of the needles, and eventually the death of the spur.

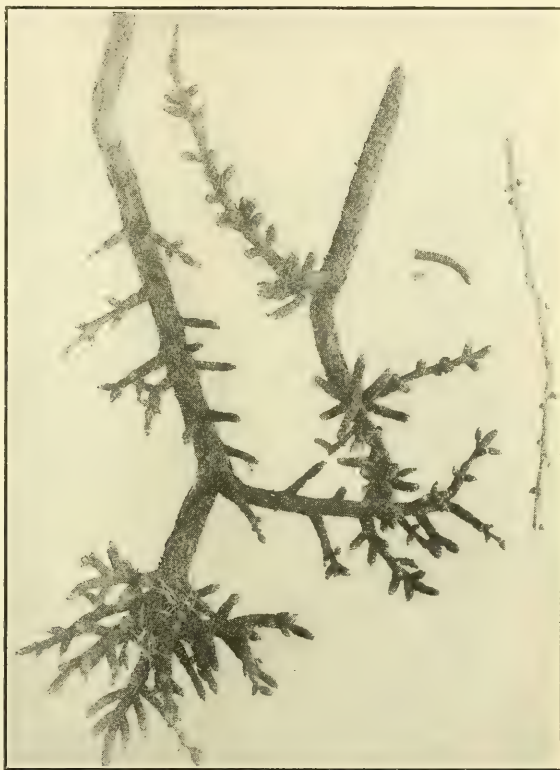


FIG. 16.—Abnormal foliar spurs of the western larch caused by *Razoumofskyia laricis*. Note their size as compared with normal spurs.

The reduction of foliage by the thinning and shortening

of the needles of the trees as a whole, and of the brooms sooner or later, is characteristic of mistletoe infection on all hosts.

The food material, which undoubtedly is accumulated in the brooms, seems to be entirely appropriated at these points and does not serve the host as a whole. The support of the excessive number of branches is necessary, but the parasite itself undoubtedly appropriates a large share at the expense of the healthy branches. The yellow-pine mistletoe has been observed to become more luxuriant and to develop abnormally long stems on swellings which had been lacerated or gnawed by rodents. Evidently the accumulation of

extra food materials in the healing tissues at this point exercised a beneficial influence on the parasite.

The actual nutritive relation between these parasites and their hosts is not at present well understood. The constant removal of all the needles of six lodgepole pines 8 to 12 years old on which large clumps of mistletoe were attached has not in the second year of the experiment resulted in the death of either the host or parasite. The controls, viz. six young pines of the same age, stripped of their needles but bearing no mistletoe plants, have died. This experiment indicates a possible transfer between the host and parasite not

only of water and inorganic salts, but of organic food materials as well. However it may be interpreted, it seems that the pines were kept alive temporarily by the mistletoe. Probably it is a mutual subsistence on stored materials. It must be remembered that the whole tendency of the activities of these mistletoes (*Razoumofskyia* spp.) is to reduce the life functions of the host to their lowest point, and this is the fact that should be of chief concern to the forester.



FIG. 17.—Area on the main trunk of a yellow pine infected by *Razoumofskyia campylopoda*. The rough, irregular bark indicates the location of the burl tissues. A few short mistletoe plants not visible in the illustration were present.

RESULT OF INFECTION ON THE TRUNK.

Another form of mistletoe injury results when infections occur during the early life of the tree, with the formation of burls on the trunk. No case is on record of any member of the genus *Razoumofskyia* effecting an entrance to its host through the mature cortex. If apparently recent infections on old parts of trees are carefully examined, the mistletoe plant will be found to have persisted from the time when the branch or trunk was young. Until it is proved by actual inoculation that the parasite is able to penetrate the mature cortex with its outside covering, commonly called the bark, the foregoing statements must remain valid.

Burls on the trunk caused by mistletoe are very common for some hosts, but vary in frequency on others. In point of frequency the western larch is most seriously affected by this kind of injury. Two types of burls occur on this tree, determined by the nature of the original infection. If the infection occurs at the base of a branch (fig. 11) and travels to the main trunk, a basal branch burl results, giving rise to a broom, which later dies, leaving a great burl, often of large proportions. If infection occurs directly on the main trunk the beginning of a trunk burl is immediately initiated. With

the increasing age of the host the burl tissues radiate outward in a fan-shaped area when viewed in cross section and soon leave an open wound, through the death of the central part of the infected wood. These two types of burl are so common on larch in mistletoe regions that the quality of the wood is seriously injured, resulting in a large amount of cull. In the several regions studied by the writer mistletoe burls on yellow pine are frequent. In one section of the city park at Coeur d'Alene, Idaho, are 30 or 40 large, old yellow pines. About half of the trees have mistletoe burls on the first



FIG. 18.—Cross section of a mistletoe burl on the yellow pine shown in figure 17. (The tape shows feet in tenths.)

log length and in most cases the parasite is still living in them, with a few scattering short aerial parts. Similar conditions prevail throughout the Spokane River Valley and around Coeur d'Alene Lake. Mistletoe burls on old yellow pine may or may not be conspicuous. Frequently there is no pronounced swelling (fig. 17) and sometimes the only means of detecting the diseased condition is by the presence of the mistletoe or an unusual roughness of the bark. A section through the tree at this point, however, shows the curly grain and the old roots of the parasite extending to the point of original infection (fig. 18). These burls are often very conspicu-

ous, large barrel-shaped swellings, from which pitch usually exudes in large quantities. Infection on one side of the tree generally results in the type of burl shown in figure 19.

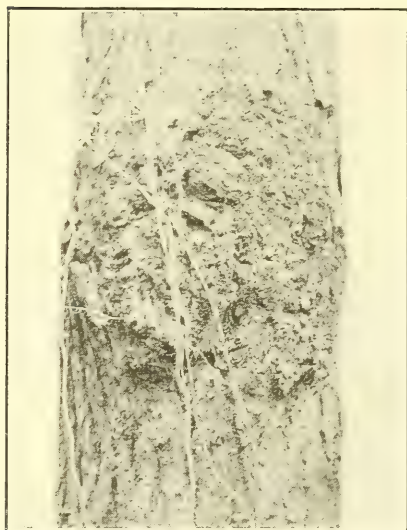


FIG. 19.—Common type of burl on yellow pine caused by *Razoumofskya campylopoda*. The tree is 3 feet in diameter at this point.

on western hemlock wherever the parasite occurs in quantity. The same is true for the mountain hemlock. In the Marble Creek region of the St. Joe National Forest mistletoe burls on the hemlock are of frequent occurrence. Allen (1, p. 20-21) writes of this type of injury as follows: "If, however, the plant gets foothold on the leading shoot, a burl follows which persists throughout the life of the tree and not only ruins a log, but renders the tree apt to be broken by the wind." Infection on the main trunk of lodgepole pine is often attended by long fusiform swellings as the parasite progresses from the original point of infection. This may continue until the bark becomes so hard that the plants can not push up through it and the spread of the parasite ceases (fig. 20). The parts

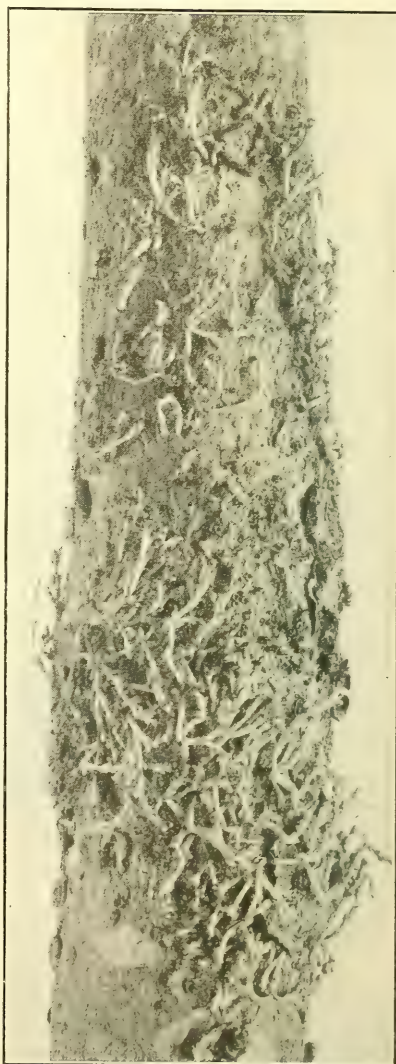


FIG. 20.—Main stem of a lodgepole pine infected by *Razoumofskya americana*. Note the spread of the parasite from the original point of infection. The bark at this point very frequently dies, leaving an open wound. (Photographed by George G. Hedgcock.)

infected, however, may continue to produce aerial branches of the mistletoe to a very advanced age. True mistletoe burls are probably of less frequent occurrence on Douglas fir than on any other economic tree species. Burls do occur, however, with sufficient frequency to be characteristic of mistletoe infection on the trunk of this tree. Large elongated mistletoe burls, including the entire circumference of the trunk, occasionally occur in heavily infected trees in many parts of Idaho and Montana (fig. 21). More frequently there is a series



FIG. 21.—Large mistletoe burl on Douglas fir caused by *Razoumofskyia douglasii*. This burl is approximately 10 feet long and 2 feet in diameter at its widest part.



FIG. 22.—A Douglas fir, showing numerous burls caused by *Razoumofskyia douglasii*. The branches are heavily broomed. A high degree of infection, but a common condition, is shown.

of individual burls, more or less confluent, on one trunk (fig. 22), each burl representing the seat of an old infection, from which the aerial parts of the parasite have long since disappeared. Longitudinal and cross sections through these burls show the characteristic fan-shaped areas of infection (fig. 23). In numerous cases the burls originate from infections at the base of branches. If the branch dies or is broken off, an open wound is formed in the center of the burl. Very peculiar swellings or small burls frequently occur on

the branches of brooms. These are sometimes so numerous as to cause the branch to resemble a chain of spherical balls. Mistletoe infection on the trunks of spruces in the East often results in the formation of burls; also on the western firs. It can be safely stated that swellings and distortions of the main trunk which persist throughout the life of the tree are a characteristic feature of mistletoe infection on most conifers of economic importance.

The spread of the burl tissues tangentially and longitudinally, which, as previously indicated, are frequently inhabited by the



FIG. 23.—Cross section of one of the burls on the Douglas fir shown in figure 22. This section does not pass through the point showing the age at which the infection first occurred. (The tape shows feet in tenths.)

parasite until a very advanced age,¹ results, as is the case with most species, in cutting off the transporting tissues and hastens the decline of the tree (figs. 20, 23, and 24). The bark and wood of the

¹ Meinecke, in 1912 (9, p. 38), records the age of a mistletoe plant (*Phoradendron juniperinum libocedri* Engelm.) at approximately 230 years. Species of the genus *Razoumofskyia* are likewise capable of maintaining themselves to a very advanced age. One instance recorded by the writer may be cited of *Razoumofskyia campylopoda*. A cross section through a mistletoe burl of this species, 3 feet from the ground, on yellow pine—a position precluding any but an original infection at an age when the bark was thin—showed that the parasite had continuously lived in the burl tissues for 340 years. The old roots, now dead except those immediately next the cambium, could be readily traced to the point of original infection. The age of the tree at this point was three years. The burl bore a single fertile aerial branch of the mistletoe. The greater mass of the cortical stroma was entirely without aerial parts, indicating the remarkable condition of parasitism first pointed out by Meinecke for *Phoradendron juniperinum libocedri*.

outer central area of the burl die soon after the death of the cortex, especially in burls on the larch, and open wounds are formed, inviting the attack of forest-tree insects and wood-destroying fungi (fig. 24). The abnormal thickness and the soft, spongy consistency of the inner bark of mistletoe-infected branches are attractive to various gnawing animals; they are also an index of the storage of food materials at this point (fig. 25).

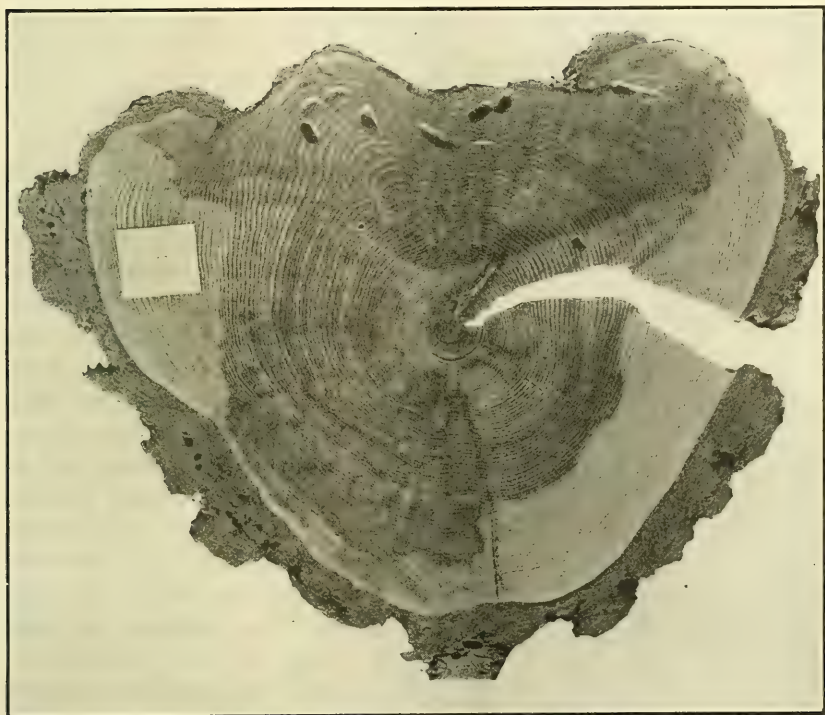


FIG. 24.—Cross section of a burl on a western larch caused by *Razoumofskyia laricis*. Diameter of burl, 2 feet. Note the presence of borers and fungi. The check appeared in seasoning.

RELATION OF MISTLETOE INJURY TO FUNGIOUS ATTACK.

Some very interesting data have recently been assembled by the writer on the relation of mistletoe burls to fungous attack. From cutting areas on the dry bench lands of northern Idaho, 540 mistletoe-infected living larches were examined. Out of 600 mistletoe burls found on these trees, 278 were inhabited by serious wood-destroying fungi and other unimportant species. According to frequency of occurrence the most important of these fungi are *Trametes pini* (Brot.) Fr., *Fomes laricis* (Jacq.) Murr., *Polyporus sulphureus* Fr. (four occurrences at 20 feet up on the trunk, a very

unusual habitat), *Trametes serialis* Fr., and *Lenzites sepiaria* Fr. *Fomes pinicola* Fr. was found rotting the heartwood of living trees in three different cases and had entered its host through mistletoe burls 10 feet from the ground. *Polyporus volvatus* Pk. occurs frequently on the burls of larch and yellow pine. Several species of Thelephoraceæ were collected from the mistletoe burls, chief of which



FIG. 25.—The soft spongy cortex of a mistletoe infection on lodgepole pine gnawed by rodents. This is a very common type of injury in mistletoe-infected trees.

were *Stereum sulcatum* Burt, *Corticium berkeleyi* Cooke, *C. galactinum* (Fr.) Burt, and *Peniophora subsulphurea* (Karst) Burt. *Ceratostomella pilifera* (Fr.) Wint., the bluing fungus, appeared occasionally in the dead wood of the burls. *Trametes pini* affected 80 per cent of all burls attacked by fungi. Since the most advanced stages of decay were always at the burl or in its near vicinity, it was assumed that the fungi had entered at this point. The decay at or in the burl tissues was in most cases not connected with the decay which is often present in other parts of the trunk. The breakage of old branches possessing heartwood, through the accumulation of brooms at their outer extremities, is likewise a means of fungi entering the tree. Not infrequently *Fomes laricis* enters its host by this

means. Mistletoe burls on Douglas fir are known to become infected with *Trametes pini*. A mistletoe burl on Alpine fir was found to be inhabited in one instance by *Pholiota adiposa* Fr. Meinecke (10, p. 58) refers to the mistletoe cankers of *Abies concolor* as offering an easy entrance to germinating spores of *Echinodontium tinctorium*. Burls on yellow pine, owing to their resinous condition, are seldom attacked by wood-destroying fungi. The bluing fungus, however, has been found by the writer in the distorted tissues of mistletoe burls on living yellow pine.

GENERAL SUPPRESSION AND FUNGOUS ATTACK.

Aside from the fact that fungous enemies enter these conifers through broken branches, lesions, and burls caused by mistletoe, heavily infected trees are, owing to their weakened condition, more susceptible to fungous attack on any part—roots, trunks, or leaves. In the lake region of Idaho the larch of all ages and conditions is at present suffering from an epidemic of a needle disease, *Hypodermella laricis* Tub. It is observed that in practically every instance the needles of very old mistletoe brooms are first attacked, whereas those of the uninfected trees of particular age classes or exposures may ward it off for a longer period.¹ It is a common observation that in regions of heavy mistletoe infection (and nowhere is it better shown than in the forests of eastern and central Oregon and many parts of Idaho and Montana) many heavily infected trees are in a dead and dying condition. If these trees are carefully examined with reference to average healthy growth for the region, it will be found that they have died prematurely.

It has already been indicated that mistletoe is capable of causing the death of its host in some instances. The whole tendency of the parasite is to reduce the life functions of its host to the lowest point, and if death does not result from this cause alone the way is opened to various secondary agents, which may or may not attack vigorously growing trees. The gradual thinning out of the foliage of heavily infected trees and the appropriation by the brooms of much of the elaborated food materials must necessarily result in an unbalanced relation between the crown and the root system. Consequently, there may be a dearth of food materials for the latter, wholly inadequate to support its present extent. It may be naturally inferred that this results in the suppression of the roots or a dying off of the more extended members of the system. A close examination of a hundred or more windfalls of heavily infected Douglas fir, yellow pine, and larch in the regions above mentioned shows quite clearly that the horizontal and brace roots of these trees in most cases were badly decayed. Since few windfalls of the heavily uninfected trees of the same average age and size were observed in the same region, it may be inferred that a possible relation existed between the suppressing effects of the mistletoe and the decay in the roots. *Armillaria mellea* (Vahl.) Quél. was definitely associated with some of the decay in the roots. In most cases, however, owing to the absence of fruiting stages, the cause of the rot in the fallen trees could not be determined.

¹ *Hypodermella laricis* was first named and described by Von Tubeuf on the European larch (*Larix europaea*). This is the first note of its occurrence in North America. The fungus, characterized by its four clavate spores to an ascus, is very destructive and is the cause of considerable damage in the larch forests of the northwestern United States and Canada.

It is a well-known fact that wounds heal quickly in young or in strongly growing trees, principally due to the protection afforded by an abundant flow of resin. It may be assumed that trees having their life functions brought to a low ebb by excessive mistletoe infections, with resulting decrease in annual increment, will not be able to heal or protect their wounds as quickly as normal trees; hence, are more liable to infection. This may be one of the reasons why so many open burls are formed on infected larches. These open burls are seldom, if ever, healed, although the parasite in its tissues has long since died. There is a slight increase in the number of resin passages in early burl formations, but this is entirely offset by the early dying out of the bark of the burl exposing the wood. It is an observed fact, experimentally proved by the writer, that strongly suppressed yellow pine, larch, and Douglas fir do not as readily form traumatic wood or exude the normal quantity of resin on being wounded on any part as do normal, healthy trees. Such a tardy reaction to injury does not afford a ready antisepsis against the entrance of fungi which may attack these trees. Since turpentine orcharding is becoming more extensively practiced in the West it would be an interesting experiment to determine the relative flow of pitch from trees strongly suppressed by mistletoe and from those in a high state of health.

RELATION OF MISTLETOE INJURY TO INSECTS.

In the same manner that burls and other types of mistletoe injury on some conifers are open doors to fungi, they are found to afford a ready means of entrance for some species of forest-tree insects which do not in this region habitually attack vigorous unwounded trees. Old mistletoe burls on larches are almost invariably attacked by borers (figs. 23 and 24), and burls on yellow pine are, in the experience of the writer, quite as frequently infested by bark and wood boring beetles. In this connection a very curious and interesting phenomenon often occurs on young yellow pines from 10 to 20 years of age. An infection by mistletoe will have occurred, completely enveloping the trunk some 2 or 3 feet from the ground. The parasite having advanced somewhat each way from the point of original infection, the intervening space is attacked by *Dendroctonus valens* Lec. The combined influence of the beetle and mistletoe results in the complete infiltration with resin of the space between the two edges of the advancing mistletoe, so that the cambium dries out and dies. Strange to state, this does not always kill the tree. The crown goes on manufacturing food materials, being supplied with water through the inner wood of the girdled area. The elaborated food not being able to travel downward, since the cambial tissues of the entire circumference of the stem have been destroyed, is stored just above the

girdled area and initiates an abnormal swelling (fig. 26). The swelling continues to increase in size and weight, likewise all members of the crown, so that eventually the slender stem below can no longer support the overdeveloped crown and is broken down by the wind. A specimen in the laboratory shows the number of rings of the stem at the girdled area at the time it was cut to be eight, with a diameter of 1 inch. The swelling just above and within the same internode showed 15 rings, with a diameter of 3 inches. The same phenomenon is sometimes produced in yellow pine by *Peridermium flamentosum* Pk. When it is recalled that the cambium and the outer wood of the girdled area are actually dead, the length of time the crown continues alive is really remarkable.

In point of general insect attack it has been noted that the beginning of an infestation may start with trees badly suppressed by mistletoe. The fact that trees heavily suppressed by mistletoe have a weak flow of sap causes them to be first selected by certain forest-tree insects. For this reason mistletoe areas form centers from which infestations may spread. Again, numerous infestations may start simultaneously over a wide territory, owing to the weakening of the trees by these parasites instead of from a few detached areas, as is often the case. This has been found particularly true in the case of yellow pine and the red turpentine beetle mentioned above. In all regions of heavy mistletoe infection of the Douglas fir, *Dendroctonus pseudotsuga* Hopk. is usually very abundant. This was the rule in the Whitman National Forest, Oreg., and though the numerous dead trees of this species in the forest were undoubtedly the result of an immediate attack by the beetles, their work was hastened, it seemed, by the serious mistletoe suppression which was exhibited by most of the dead trees. During the season

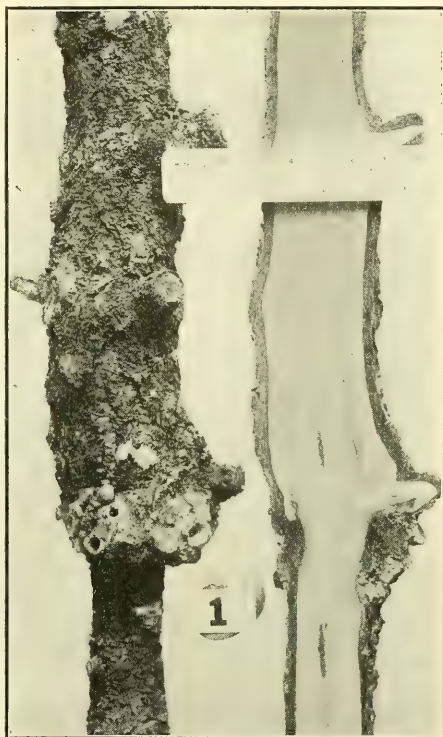


FIG. 26.—A young yellow pine, showing complete girdling of the stem by a combined attack of mistletoe and insects. The cambium is destroyed, but the crown remains alive and continues to elaborate food materials, which are stored just above the girdled area.

of 1914, a large number of badly suppressed Douglas firs on the foothills bordering the Clark Fork (Missoula River) Valley have died from a combined attack of mistletoe and beetles. Most of these trees, which supported scarcely a single normal branch, had the bark of limbs and trunk almost entirely removed by woodpeckers in their search for the beetle before the leaves were entirely dead. The few uninfected Douglas firs of the same region have not been attacked by the beetles.

The branches of large mistletoe brooms on yellow pine and Douglas fir from which the parasite has entirely disappeared are very

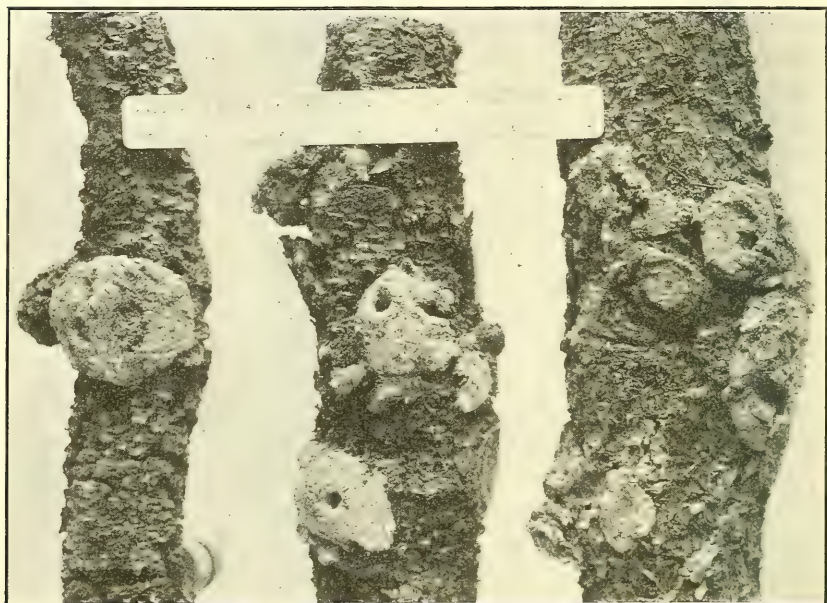


FIG. 27.—Seats of original mistletoe infection on two living branches (in center and at left) of mistletoe brooms on yellow pine infested with bark beetles. No other part of the broom or tree was attacked. Main stem of young living yellow pine (at right) attacked by bark beetles at the seat of an old mistletoe infection.

frequently found infested with bark beetles (fig. 27), while the trunk and normal branches of the trees are entirely free from attack.

INFLUENCE OF MISTLETOE INJURY ON THE SEED PRODUCTION OF THE HOST.

Germination tests of seeds of yellow pine taken from mistletoe-infected trees show that the percentage of germination is considerably lower than is the case with seeds taken from normal trees (12, p. 7). Experiments conducted by the writer with seeds taken from cones produced on very old mistletoe brooms of Douglas fir, larch, and lodgepole pine showed a germination on an average of 10 per cent below that of seed taken from uninfected branches of

the same trees. Given the general average percentages of germination of 30 for the former and 40 for the latter, it seems that either from exhaustion of stored materials or tendencies toward abnormal seed production in general the uninfected branch, though suppressed, is still capable of producing a higher quality of seed than the broom. Whether this would be true in the case of young, vigorous brooms is doubtful. Seeds from the uninfected branches of the same strongly suppressed trees used in the above experiment gave a general average of 15 per cent below that of seeds taken from vigorous uninfected trees of the same age, species, and habitat. The percentage of 65 for the uninfected and 40 for the infected shows quite clearly that suppression by mistletoe causes a serious falling off in the quality of the seed of its host.

The experiment was conducted in the following manner. Collections of cones were made from each of five strongly suppressed and five uninfected trees of all three species. This included one collection from the brooms, one from the uninfected branches of each of the suppressed, and one collection from each of the uninfected trees; in all, 45 different collections. One hundred seeds were extracted from each collection and germinated in sand at an average temperature of 35° C. Counts were made at different intervals during the progress of the test, which was continued for 90 days. Considerable difficulty was experienced in procuring the required number of seeds for all conditions, owing to the sterility of the cones on the old brooms. With the increasing age of the broom the seed production falls off, until, as it is with most species, no cones are produced at all. Seeds from recently formed brooms were not tested. It is supposed that they would show a higher percentage of germination. The cones on badly suppressed trees are very often aborted, with shriveled, undeveloped sporophylls, and are frequently infested by cone beetles and cone worms. Seeds, if produced in such cones, are usually below the normal size. A study of microtome sections of the staminate flowers from heavily infected lodgepole pine showed that there was a reduction in the number of pollen mother cells. The staminate flowers when compared with those of normal trees of the same age and condition were found to be uniformly smaller. The sporophylls on the more fertile or convex side of the young pistillate cones very frequently bore only one ovule (megasporangium), a condition not observed in cones from healthy trees.

HOST AFFINITIES IN RELATION TO SILVICULTURE.

For practical purposes the following statements on the host requirements of the mistletoes of coniferous trees will be found to be of some interest with regard to the silvicultural management of forests.

Razoumofskya douglasii (Engelm.) Kuntze is of economic importance only on the Douglas fir. The affinities of the very small and rare forms of *Razoumofskya* on spruce and fir,¹ described by Engelmann (6, p. 253) under the name of *Arceuthobium douglasii* var. *microcarpum* for the former host and *A. douglasii* var. *abietinum* (3, v. 2, p. 106) for the latter, are not definitely established. In point of time of blooming and seed maturity, it coincides with that of *Razoumofskya douglasii* for northern regions, and their form and color are quite similar, especially the color of the staminate flowers. These small plants, together with the Douglas fir mistletoe, are the only members of the genus exhibiting a pronounced color of the lobes, which are a bright, deep purple. Until cross-inoculation experiments are perfected, these particularly small mistletoes on spruce and fir may be considered wholly unimportant from a silvicultural standpoint. For the sake of convenience, they may be placed with the Douglas fir mistletoe and the whole designated as the *Pseudotsuga-Abies-Picea* group, characterized by their small size and colored flowers. *Razoumofskya laricis* Piper, the most universally distributed and probably the most injurious of the entire genus, is associated with the western larch. This species in a single instance has been collected by the writer on lodgepole pine near Missoula, Mont. It is a significant fact that this infection is not vigorous and appears to be dying out. *R. americana* (Nutt.) Kuntze is more strictly associated with the lodgepole pine, but is the cause of serious damage to the jack pine (*Pinus banksiana*) where these two species approach each other in Canada. *R. tsugensis* Rosend., as far as observations in the field have gone, is confined to the hemlocks.

The remaining species of importance may be divided into two main groups, a fact that has not been heretofore set forth, viz, those associated with the soft or white pines and those attacking the hard yellow pines. It seems that the members of one group are not in a single instance associated with the hosts of the opposite group. The former group includes the following species and hosts: *Razoumofskya divaricata* (Engelm.) Coville on the nut or piñon pines, *P. edulis* and *P. monophylla* (6, p. 253); *R. cyanocarpa* A. Nels. on *P. flexilis* (4, p. 146), *P. albicaulis*, and *P. monticola*. *Pinus monticola* has not been previously reported as a host for these parasites. *Pinus strobiformis*, the Mexican white pine, is reported (11, p. 65) as the only host of *R. blumeri* (A. Nels.) Standley. The second group may be included by the two-form species: *R. campylopoda* (Engelm.) Piper and *R. cryptopoda* (Engelm.) Coville. The former is principally injurious to *Pinus ponderosa*, but is common on *P. attenuata* (7, p. 366; 13) and *P. jeffreyi* (10, p. 38). The latter is likewise an injurious parasite on

¹*Abies concolor* is also host for *Phoradendron bolleanum* (Seem.) Eichl. (5, p. 193).

P. ponderosa, but occurs on *P. jeffreyi* (5, p. 192), *P. arizonica* (2, p. 243), and *P. mayriana* (2, p. 243). *R. campylopoda* has recently been collected by the writer near Coeur d'Alene, Idaho, on *P. contorta*. Sparingly distributed throughout the Northwest are some large forms of *Razoumofskya* on *Abies*. Plants collected by the writer on *Abies grandis* and *A. concolor* are apparently the same as that described by Engelmann (3, v. 2, p. 106) on the former host under the name *Arceuthobium occidentale* var. *abietinum*. Although it would probably be better on morphological grounds to refer this form to *R. campylopoda* (Engelm.) Piper, as Engelmann's *Arceuthobium occidentale* is now named, owing to its seeming close affinity to the genus *Abies* and the absence of cross-inoculation data it could well be raised to specific rank. These mistletoes in point of morphology are in great contrast with the small forms on *Abies* previously mentioned. They may be considered typical of a group of large forms occurring only on *Abies*.

From the foregoing, it seems possible that the members of the genus *Razoumofskya* may be arranged in a series of natural groups according to their host relationships. It is also interesting to note that the largest, the longest lived (both cortical and aerial parts), and the most strictly parasitic forms are associated with the hard or yellow pines. These pines exhibit anatomically a high differentiation. This may throw some light on the nutrient relation of some mistletoes to their hosts; also their family peculiarities.

SUGGESTIONS FOR CONTROL.

It is clear from the foregoing pages that the damage to forest growth by the mistletoes of coniferous trees in the Northwest is of sufficient importance to receive the attention of every forester. Steps should be taken in all logging operations, where local problems of economy do not interfere, to make a beginning of the eradication of mistletoe by marking every infected tree for cutting. In some cases it would seem advisable to introduce into the contract a special clause dealing wholly with mistletoe-infected trees. The most injurious of the mistletoes of the genus *Razoumofskya* on coniferous trees, as indicated; are in the main confined to their own particular hosts or to special groups; hence, it is not advisable to establish in mistletoe regions pure stands of a species much subject to attack. In this respect the problem of the control of mistletoe is similar to that of forest-tree fungi. Mistletoes being light-loving plants, close stands should be maintained as much as possible on all exposed parts of the forest. For the same reason rims of canyons and all exposed areas, such as the borders of bench lands, natural parks, shores of lakes, etc., should be protected with species which are not usually subject to the ravages

of mistletoes (Pl. IV, fig. 2). In this class would fall the firs, spruces, arbor vitas, cedars, junipers, and yews. If this can not be done, owing to certain requirements by these species on soil and climate, the stand should be composed of as many different species as possible.

Aside from reasons already set forth, isolated seed trees heavily or even slightly infected by mistletoe should not be retained. The vigor of the parasite on the parent tree will become greater, owing to its response to open and well-lighted conditions. Reproduction under the tree and in its near vicinity, if of the same species, will readily become infected. The same will be true of seed plats. The force developed within the mature seed capsule of these mistletoes and exerted in the expulsion of the seed is a factor of great significance for the spread of the parasite. It has been demonstrated in the case of one species that this force is sufficient, starting at an elevation of 8 feet on the level, to carry the seed a distance of over 66 feet. In addition to the forcible expulsion of its seeds by the parasite, strong wind is an important factor in seed dissemination. In one instance seeds of the larch mistletoe were collected in number from the roof of a cabin one-fourth of a mile away from the nearest infected tree. This is not at all extraordinary, in view of the fact that the larches of the region are very tall and are heavily infected in the crown. Also strong winds are frequent during the period of seed maturity. Birds and animals play a minor rôle in the distribution of the seeds of these mistletoes.¹ In the present instance, however, the seeds adhered to the substratum in the usual and normal manner and could not have been transported in such numbers by any other means than strong wind.

In view of the fact that strong air currents are factors in the dissemination of the seeds, some consideration should be given to the topography and prevailing winds of a region where mistletoe abounds, as influencing the selection of seed plats (if such methods are employed), the placing of strip cuttings, and even of nursery and transplant beds. On a previous page, the tender age at which coniferous seedlings are liable to infection by mistletoe is indicated, so that the above statement regarding nursery sites is not merely a conjecture. Since considerable time elapses between the actual penetration of the primary sinker and the time the infection becomes conspicuous, three years in some instances, it is quite possible for

¹ In Bulletin 317 of the U. S. Department of Agriculture, page 24, the writer published a footnote on the rôle of birds and animals in the distribution of the seeds of these mistletoes. Since this publication was issued additional observations show that the seeds are probably more widely distributed by this means than was formerly believed. A rumor has been long extant that grouse feed upon the mistletoes. This has recently been verified by the writer by finding in the crop of a grouse the mature seeds and plants of the Douglas fir and larch mistletoes. Mr. Donald Morrison, an old, experienced hunter residing in the mountains near Missoula, states that grouse in the late fall, with the coming of the winter snows, make a practice of congregating in the dense houselike brooms of the Douglas fir mistletoe. Mr. Morrison states quite positively that these birds feed upon the plants and mature seeds of these parasites when other forms of food become scarce.

young infections on nursery stock to escape detection. Accordingly, young infected seedlings may become a means of distributing and establishing the parasite in plantations generally, not only locally but to far distant regions, when growing stock is shipped either for experimental purposes or for permanent plantings. That this is possible is shown by the discovery in the planting areas near Wallace, Idaho (Coeur d'Alene National Forest), of a yellow-pine seedling showing a very recent infection of mistletoe. Since the plantings were made on a widely denuded area and no yellow-pine mistletoe is as yet known to occur in the immediate region, it seems that the seedling must have become infected while at the home nursery at Boulder, Mont., where this mistletoe occurs. In view of the fact that there is a very grave danger of transporting agents injurious to forest growth, either fungous diseases or mistletoe, by sending nursery stock to distant parts of the country, the need of strict sanitation in the neighborhood of forest-tree nurseries can not be overemphasized. Whenever new nursery sites are planned in or near forests, a close pathological survey should be made of the surroundings, and trees diseased or suppressed from any cause whatever should be cut out. This should be done also where nurseries are already established.

The influence of the physical type on the severity of attack should receive considerable attention in any plan of management of forests in mistletoe regions. Forest Assistant Gilkey, in a report on the western larch of the Whitman National Forest, states that "a total of several hundred trees in various parts of the forest shows 79 per cent of the larch to be attacked on the dry-slope type, with only 27 per cent on the more moist sites." The writer's own investigation in the same forest shows an even greater difference between the moist-valley type and the more exposed slopes, which was 87 per cent for the latter and 15 per cent for the former. The severity of the infection on yellow pine and Douglas fir in other regions likewise shows wide extremes as influenced by elevation and exposure. Mr. E. E. Hubert, of the Laboratory of Forest Pathology, reports from extensive observations during a reconnoissance of the lodgepole pine in the Big Hole Valley, Mont., that the most favorable sites for mistletoe are exposed dry ridges and south slopes, where the infection ranges from 50 to 70 per cent of the stand. In the valley type the percentage of infection was much lower.

In view of the fact that all economic species so far observed are subject to attack at any age, it is hardly possible to establish an age at which infection becomes so serious as to interfere with the merchantability of the host. In regions of heavy mistletoe infection it would be quite impossible, for the reason that there is a much greater chance for all age classes to become infected. In numerous in-

stances, however, it is noted that in some regions Douglas fir, larch, and lodgepole pine first become conspicuously infected at sapling or pole size; that is, it has required several years for earlier infections to become prominent. In any case, the matter turns on the time of life at which a tree becomes infected. If seriously infected before pole size is reached, the whole tree will in all probability be a cull and a menace to the forest. If infected during or after pole age, the tree may furnish some merchantable material, but will mature far in advance of uninfected trees of the region. Trees infected during early maturity may not be seriously influenced by the parasite except that their life functions may be slightly changed by brooming and breakage of branches, thus hastening the period of decline. Cutting old and suppressed mistletoe trees is, of course, a saving in several ways, not only to the future forest, but it is getting the best out of a rapidly declining forest capital. Their destruction, however, does not mean that a great advance is being made in eradicating the mistletoe from the region. It simply lessens the chance of infection for a time. Cutting the old and merchantable infected trees and leaving the younger unmerchantable but infected growth will not answer the purpose of control in regions of heavy infection. Very frequently the removal of only the more merchantable mistletoe trees causes the parasite on the trees that are left to develop more vigorously. Numerous observations show that infected trees of various ages succumb very rapidly to the parasite after a certain percentage of the stand has been cut out. For this reason marking the most seriously infected trees for cutting, with the prospect of the least infected reaching a normal maturity or a state of high merchantability, should in many regions be discontinued. The only plan left, then, in many regional units of infection is to practice heavier marking than hitherto employed, or, better still, clean cutting. It is believed that a close survey of the forests of each district will result in the discovery that there are units or centers of great infection either for one species of mistletoe or for different species.

Instances of great regional infection for the Northwest have already been indicated. Strange to say, in some cases these centers of infection are quite sharply defined. It seems entirely possible that if these regions were carefully studied and mapped as to the possible environmental factors governing the vertical and horizontal distribution of the parasite, much practical knowledge would result. If the region should be accessible, the sales policy could be modified, with strong emphasis on the control of the mistletoe, and the knowledge already gained from a detailed study of the region should be available for future forest management. It must be remembered that the great injury now exhibited by forest growth is the accumulation of many years of unhindered activity by these

mistletoes. Through a proper appreciation of the need of adopting control measures in all sales areas where the percentage of infection is high and in all replanting projects in mistletoe regions, with the free-use privileges of mistletoed trees and the cutting of all infected growth in the vicinity of forest-improvement stations, a good beginning could be made toward the eradication or the lessening of the ravages of these parasites.

SUMMARY.

The conifers in the Northwest most subject to injury by mistletoes of the genus *Razoumofskyia* are *Larix occidentalis*, *Pinus contorta*, *Pseudotsuga taxifolia*, and *Pinus ponderosa*. In the order of the above-named hosts the mistletoes most responsible for the greatest damage are *Razoumofskyia laricis*, *R. americana*, *R. douglasii*, and *R. campylopoda*.

The general nature of the injury by these mistletoes is expressed in a gradual reduction of the leaf surface of the host, which causes a great reduction of growth in height and diameter.

New infections take place only through the agency of a germinating seed, which reaches the point of infection through the natural expelling force of the seed capsule, which may be made more effective in point of distance traveled by the aid of strong winds, by falling from branches above after they have been loosened from their original resting place by rains, and by animal life.

Trees of all age classes are liable to infection provided the mistletoe seeds fall on parts of the host not yet protected by the mature cortex. The parasite may spread from the original point of infection into older cortical tissues, which are not liable to infection from without. The spread of the cortical stroma in the reverse direction from the line of growth of the branch may continue until the outer cortex becomes too thick for the aerial shoots to penetrate it. After this, the cortical roots become suppressed and eventually die, or they may become wholly parasitic.

Excessive mistletoe infection of the lower branches of a tree may cause the upper portion of the crown to die, giving rise to the phenomenon commonly called staghead or spiketop. Severe infection throughout the entire crown often results in the death of the tree. Young seedlings from 3 to 6 years old are often killed within a comparatively short time after infection.

Infection on the branches in practically all cases causes the formation of large brooms, which seriously interfere with the life function of the tree. The same is true in the case of infection on the trunk, whereby burls are formed.

The weakening effect of the formation of burls and brooms by mistletoe on forest trees is often responsible for serious depredations by fungi and forest-tree insects.

In point of quality and quantity the seed-producing capacity of trees suppressed by mistletoe is far below that of normal uninfected trees.

Mistletoe can be controlled. It is suggested that a beginning may be made in its eradication or in the reduction of the ravages caused by these parasites by working along the lines indicated in the last section of this bulletin.

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COMPARISON OF THE BACTERIAL COUNT OF MILK WITH THE SEDIMENT OR DIRT TEST.

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UTILITY OF THE SEDIMENT TEST.

The sediment or dirt test has been used for some time as a means of detecting visible dirt in milk. It was first applied in Europe to grade the milk as it arrived at the milk-receiving stations. After the milk had passed through the cotton disks they were cut in two, one part being kept for reference and the other mailed to the producer. In this manner it was found to be valuable in inducing the farmer to produce cleaner milk.

During the past few years the sediment test has gained great favor among milk inspectors in this country. They say it has been of great value, as they can actually show the farmer when his milk is insanitary and in this way better fix a standard of prices at the milk-receiving stations. Until recently the grading of milk and cream at receiving stations was based entirely upon such tests as those for per cent of fat, acidity, odor, etc. No test was used whereby any information could be gained regarding the sanitary conditions under which the milk was produced.

Since the discovery of the sediment or dirt test the grading or judging of milk at receiving stations has been of two kinds, chemical and hygienic. It has been the opinion of inspectors that when milk contained sediment or dirt it was insanitary, but until the discovery

of the sediment test they never had a means of quickly determining the exact amount. It has also been a fact long and fairly well established that milk containing sediment or visible dirt, such as manure, hair, etc., was produced under insanitary conditions, but when these ingredients were not present in the milk no field inspector could determine its purity.

Upon the adoption of the sediment test as a means of detecting insanitary milk at the milk-receiving stations, the producers undoubtedly began to use methods calculated to remove the visible dirt. Such methods have been resorted to as straining the milk through cotton, cheesecloth, and Canton flannel to prevent the detection of visible dirt at the station by the field inspector. These methods have so changed the value of the sediment test as a means of judging pure milk that when no sediment or visible dirt can be detected it is often almost impossible to state whether the milk is produced under sanitary conditions or not. In order to determine whether the sediment test could be wholly relied upon as a means of detecting insanitary milk at milk-receiving stations, an experiment was conducted with this purpose in view.

OBJECT OF THE WORK.

The object of this experiment was to prove whether milk containing little or no visible dirt, as often occurs when filtered through certain substances by gravity, was free from a large number of bacteria. It was decided that by comparing the bacterial count with the sediment test (also when milk was filtered through various utensils) certain information could be obtained regarding this point.

OUTLINE OF EXPERIMENT.

Briefly, the experiment was conducted as follows:

Three of what we considered the most practical sediment-test apparatuses were used, namely, the Gerber, the Wizzard, and the Lorenz. The Gerber apparatus was selected because it represents a gravity method. The average length of time required for one pint of milk to pass through the disk by this method was 15 minutes. The Wizzard was selected as a pressure type which could be easily carried for field work and attached to the milk bottle without removing the milk. By this method the time required for the milk to pass through the disk was about two minutes; its disadvantage was that when the pressure was applied there was no means of holding the apparatus securely to the bottle. The Lorenz apparatus was selected as a pressure type in which the milk is placed in the metal container and the pressure applied. The time required by this

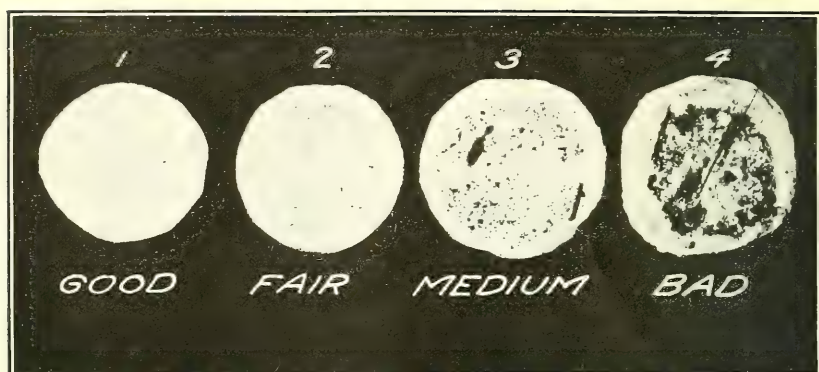


FIG. 1.—COTTON DISKS SHOWING FOUR DEGREES OF SEDIMENT FROM MILK.

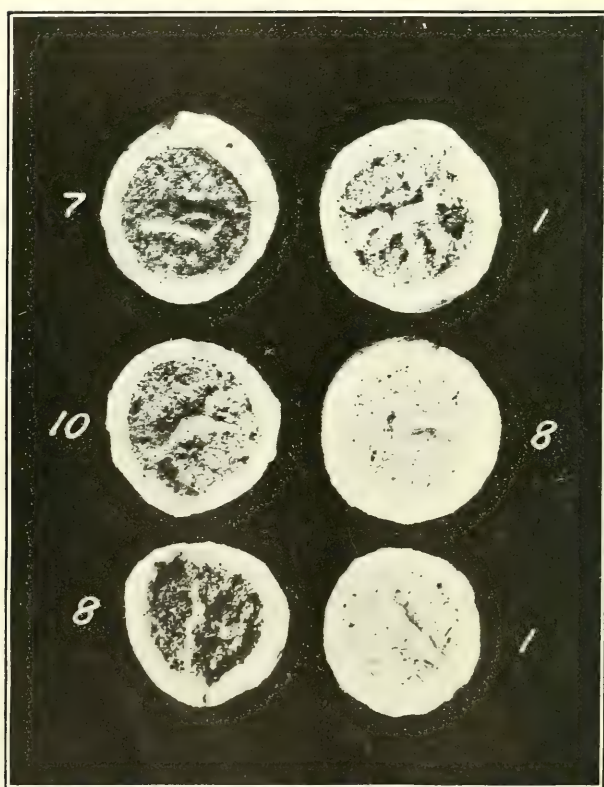


FIG. 2.—COMPARISON OF DISKS IN PAIRS RESULTING FROM THREE KINDS OF SEDIMENT TESTS.

method was also about two minutes, and we found it to be the most satisfactory for field work.

Fifty samples of milk were collected on the railroad station platform from milk cans as they arrived from various farmers throughout the section. Upon arrival at the laboratory the temperature was taken and a bacterial count made. After preparing plates each sample was passed through one of Gerber's sediment tubes. The sediment disks were kept and compared with the bacterial count. A similar comparison was also made with the Wizzard and Lorenz apparatuses, using 50 samples in each case.

After 50 samples had been tested with each apparatus, 20 samples were filtered through 4 pieces of cheesecloth, 20 through one thickness of absorbent cotton, and 20 through one of Canton flannel. Each of these samples was then subjected to the sediment test and a bacterial count made in each case; this was done to determine the effect that straining the milk would have upon the test. We also made a comparison of the filtered samples with the bacterial count after passing them through the cotton disks used in the Lorenz apparatus.

The writer wishes to thank Dr. John R. Mohler, assistant chief of the Bureau of Animal Industry; Dr. Louis A. Klein, dean of the veterinary school, University of Pennsylvania; and Dr. C. J. Marshall, State veterinarian of Pennsylvania, for many valuable suggestions in the work.

METHOD OF COLLECTING SAMPLES.

The milk in the can was thoroughly shaken and 1 pint taken as a sample. The sediment in this kind of sample would, in our opinion, represent the amount of dirt contained in an ordinary bottle of milk. A few inspectors believe that the sample should be collected from the bottom of the cans before shaking, but it seems to us that this may at times be unfair to the producer.

DETAILS OF THE EXPERIMENTS.

In our experiments the character and quantity of sediment upon the cotton disks is represented by the words "good," "fair," "medium," and "bad." (Pl. I, fig. 1.) This gives four classifications, which we considered sufficient for all practical purposes. These classifications are illustrated in Plate I.

COMPARISONS WITH UNFILTERED MARKET MILK.

Table 1 shows the laboratory results obtained by comparing the bacterial count with the Gerber sediment test on 10 average samples out of 50.

TABLE 1.—*Comparison of bacterial count with Gerber sediment test (unfiltered market milk).*

Sample No.	Bacteria per cubic centimeter.	Character of sediment.	Sample No.	Bacteria per cubic centimeter.	Character of sediment.
1.....	2,690,000	Fair.	6.....	1,206,000	Fair.
2.....	1,812,000	Medium.	7.....	108,000	Bad.
3.....	1,537,000	Good.	8.....	263,000	Good.
4.....	189,000	Bad.	9.....	1,803,000	Fair.
5.....	643,000	Medium.	10.....	319,000	Medium.

In these results it will be seen that some samples had a high bacterial count, yet tested "good" or "fair" with the sediment test, while others which had a low bacterial count tested "medium" or "bad."

Plate I, figure 2 (upper), shows two of the samples—No. 7 and No. 1. No. 7, having a large amount of sediment and classed as "bad," has a low bacterial count, while the other, No. 1, is classed as "fair," and has a high bacterial count.

Table 2 shows the tabulated results obtained by comparing the bacterial count with the Wizzard sediment test on 10 average samples out of the 50.

TABLE 2.—*Comparison of bacterial count with Wizzard sediment test (unfiltered market milk).*

Sample No.	Bacteria per cubic centimeter.	Character of sediment.	Sample No.	Bacteria per cubic centimeter.	Character of sediment.
1.....	2,131,000	Fair.	6.....	246,000	Bad.
2.....	622,000	Good.	7.....	3,558,000	Fair.
3.....	1,391,000	Do.	8.....	4,102,000	Good.
4.....	812,000	Bad.	9.....	2,688,000	Fair.
5.....	377,000	Do.	10.....	243,000	Bad.

It will be seen here that a greater difference occurred than in the preceding table.

Plate I, figure 2 (middle) shows disk No. 8, classed as "good," containing 4,102,000 bacteria per cubic centimeter, while disk No. 10, classed as "bad," contained only 243,000 per cubic centimeter.

Table 3 shows the tabulated results obtained by comparing the bacterial count with the Lorenz sediment test on 10 average samples out of 50.

TABLE 3.—*Comparison of bacterial count with Lorenz sediment test (unfiltered market milk).*

Sample No.	Bacteria per cubic centimeter.	Character of sediment.	Sample No.	Bacteria per cubic centimeter.	Character of sediment.
1.....	768,000	Fair.	6.....	48,000	Fair.
2.....	99,000	Good.	7.....	27,000	Do.
3.....	63,000	Bad.	8.....	7,200	Do.
4.....	57,000	Do.	9.....	329,000	Do.
5.....	34,000	Do.	10.....	49,000	Good.

This table, like the others, shows considerable variations; No. 1, which had a bacterial count of 768,000, tested "fair" by the sediment test, and No. 8, which has a count of 7,200, tested "bad." These disks are shown in Plate II (lower).

COMPARISONS WITH FILTERED MILK.

After comparing the bacterial count with the various sediment tests of unfiltered market milk, it was decided to make a comparison after the milk was filtered through such substances as are frequently used as strainers by farmers to remove dirt. Twenty samples were filtered through 4-ply cheesecloth and the Lorenz disks compared with the bacterial count.

The table below shows the results obtained from 10 average samples out of 20; filtering through cheesecloth.

TABLE 4.—*Comparison of bacterial count with Lorenz sediment test (milk filtered through cheesecloth).*

Sample No.	Bacteria per cubic centimeter.	Character of sediment.	Sample No.	Bacteria per cubic centimeter.	Character of sediment.
1.....	109,000	Good.	6.....	33,000	Good.
2.....	67,000	Do.	7.....	84,000	Do.
3.....	46,000	Do.	8.....	93,000	Do.
4.....	24,000	Do.	9.....	54,000	Do.
5.....	639,000	Do.	10.....	316,000	Do.

Twenty samples were filtered through one ply of Canton flannel and the bacterial count compared with the Lorenz disks. Table 5 shows the results obtained from 10 average samples out of 20.

TABLE 5.—*Comparison of bacterial count with Lorenz sediment test (milk filtered through 1-ply Canton flannel).*

Sample No.	Bacteria per cubic centimeter.	Character of sediment.	Sample No.	Bacteria per cubic centimeter.	Character of sediment.
1.....	78,000	Good.	6.....	19,400	Good.
2.....	31,000	Do.	7.....	316,000	Do.
3.....	41,000	Do.	8.....	129,000	Do.
4.....	108,000	Do.	9.....	149,000	Do.
5.....	18,000	Do.	10.....	119,000	Do.

Twenty samples were filtered through 1-ply ordinary absorbent cotton, covered above and below with 1-ply cheesecloth. The Lorenz disks were compared with the bacterial count, as in the preceding table. Table 6 shows the results obtained from 10 average samples out of 20.

TABLE 6.—*Comparison of bacterial count with Lorenz sediment test (milk filtered through 1-ply absorbent cotton and cheesecloth).*

Sample No.	Bacteria per cubic centimeter.	Character of sediment.	Sample No.	Bacteria per cubic centimeter.	Character of sediment.
1.....	760,000	Good.	6.....	57,000	Good.
2.....	67,000	Do.	7.....	362,000	Do.
3.....	31,400	Do.	8.....	471,000	Do.
4.....	42,000	Do.	9.....	48,000	Do.
5.....	61,300	Do.	10.....	191,000	Do.

In every instance in which the milk was filtered through any substances to remove visible dirt the disks were classed as good.

It would seem from the results shown in the last three tables that if milk is strained before applying the sediment test the latter is of little, if any, value in estimating visible dirt.

CONCLUSIONS.

1. The writer considers the Lorenz apparatus the most convenient and practical for demonstrating dirt in milk.

2. The quantity of sediment or visible dirt present on the disk is no criterion as to the kind or number of bacteria contained in the milk.

3. The various sediment tests are applicable only in roughly estimating the quantity of sediment in unstrained milk, and can not be used solely as a means of determining the hygienic conditions under which it was produced.

4. If milk is strained through the substances mentioned, the sediment testers are of little value in estimating the degree of contamination.

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- Comparison of Bacteria in Strained and Unstrained Samples of Milk. H. W. Conn and W. A. Stocking, Storrs Agricultural Experiment Station Bulletin, 1903-1905.

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of a Milking Machine; 2, Bacteriological Studies of a Milking Machine (Bureau of
Animal Industry Bulletin 92). Price, 15 cents.
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Methods of Classifying the Lactic-acid Bacteria (Bureau of Animal Industry Bulletin
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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 362



Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



May 6, 1916

A SYSTEM OF ACCOUNTS FOR PRIMARY GRAIN ELEVATORS.

By JOHN R. HUMPHREY, *Assistant in Market Business Practice*, and W. H. KERR, *Investigator in Market Business Practice*.

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INTRODUCTION.

The rapid growth of the business of primary grain elevators has emphasized the importance of adequate accounting systems. It has been realized that the adoption of a uniform system sufficiently comprehensive to accommodate itself to the conditions prevailing in the grain-producing States would be a step in advance. This bulletin describes a grain elevator accounting system which has been devised by the Office of Markets and Rural Organizations and which is now being used by representative elevators in all of the leading grain-producing States.

In drawing up the various forms comprising this system reference has been made to many other systems now in operation. A first-hand study of conditions existing in the elevator business has likewise had a bearing on the final form of this system.

NOTE.—This bulletin is intended for all primary grain elevators throughout the United States. It contains copies of forms and a description of their uses for a system of accounts which is being recommended by the Office of Markets and Rural Organization, United States Department of Agriculture, as a uniform system for primary grain elevators.

TYPES OF ELEVATOR ACCOUNTING SYSTEMS.

Investigations in respect to accounting in grain elevators have established the fact that no system has been generally accepted as standard. The idea of double-entry bookkeeping, while existing in a thorough sense in only a limited number of elevators, is followed more or less vaguely in all, and for that reason there is found every variation in type from patented systems to mere handbook entries kept in memorandum form for the benefit of the manager.

All the systems of bookkeeping now existing in elevators may be classified under three general headings: Complete double-entry systems kept in the elevator; incomplete systems, consisting of reports and memoranda kept in the elevator; and complete systems of reports made up at the elevator and sent to some outside agency where the records of the company are kept.

Of the three, the first should prove the most satisfactory for the reason that, although the third system may furnish definite information, the details of that information are not, as a rule, within easy reach of the men who are most interested in them.

The benefits to be derived from a complete double-entry system of bookkeeping, so constructed that it can be adopted by all elevators, are: First, the possibility of distributing and interchanging valuable statistics among elevators; second, the training of managers and bookkeepers, so that they will obtain a cumulative knowledge of elevator accounting, thus making it easier to procure competent help in these lines; third, the individual benefit derived by each elevator from knowing its financial and business condition with accuracy at short notice; and, fourth, the benefit to future buying in being able to ascertain the average net cost per bushel of operating an elevator.

OFFICE EQUIPMENT.

No system of accounts can be efficient unless it is properly handled. Office equipment is one of the important factors relating to the success of office work. An elevator office should be equipped with fireproof safes or a vault in which all valuable records of the company should be kept. It should have proper filing devices and sufficient furniture, including a standard bookkeeper's desk, to make thorough work possible. When the business of an elevator is large enough to justify the employment of a bookkeeper, such trained help should be secured, as, in most instances, the elevator manager is either without the knowledge or the time to perform the duties of a bookkeeper.

TAKING AN INVENTORY.

At the end of the business year or at the "cut-off," an inventory should be taken. This should be an actual physical inventory, taken either by measurement of the grain in the bins or by running it out of the bins and through a hopper or automatic scale, thus getting actual weights. The practice of taking estimated inventories by reference to the reports accumulated during the year's business is dangerous and, in most cases, absolutely inaccurate. The average platform scale has a weighing error of from 3 to 15 pounds per 60-bushel load. This weighing error accumulating during a whole year sometimes amounts to a shortage or "overage" of hundreds of bushels. By taking inventories from grain reports, the elevator may, after five or six years, find itself with a book grain stock out of all proportion to the actual grain on hand at the time of inventory. By taking an actual inventory, the shrinkage or "overage" of each kind of grain is accounted for within the year to which it applies, and, if abnormal, can be checked up easily if an actual inventory has been taken the season before.

AUDITING THE BOOKS.

One of the features in elevator bookkeeping upon which great stress should be laid and to which an important position should be assigned is the auditing of the books as soon as the inventory has been taken. The custom prevailing among farmers' elevators of having internal audit committees furnished from the board of directors or the stockholders is commendable only to the extent of its usefulness in keeping the directorate in close touch with the business of the elevator. The positive value of such an audit, in so far as it is able to detect errors of principle or even clerical errors, is negligible, since, as a rule, the men making the audit are not especially trained for such work and use very little time to complete their reports. It should be apparent, then, that it is good business practice to secure the services of a certified public accountant who has had sufficient practice in elevator accounting to be able to give vital information and advice to the manager and directors of the elevator. Internal audit committees may work in conjunction with such an auditor, thus shortening the period of his labors as well as benefiting themselves by contact with him. The item of cost in connection with the hiring of public accountants has been the deterrent factor which, to a great extent, has kept the farmers' elevators in the past from availing themselves of such services. By banding together, several elevator companies might give an accountant steady employment throughout the year and secure his services at a greatly reduced rate.¹

¹ For further discussion of auditing, see U. S. Department of Agriculture Bulletin No. 173—Cooperative Organization Business Methods.

HEDGING.

As a protection or insurance against loss from price fluctuations between the time of purchase and the time the grain is sold, an elevator may hedge its holdings. When grain is taken into the elevator it can be immediately protected by its sale for future delivery. When the grain is sold the hedge is taken up; that is, a purchase for future delivery is made. If the price of cash wheat has fallen in the meantime, the loss is counterbalanced by the profit on the hedge, as the future price will have decreased with the cash price. In this manner an elevator protects itself against loss by the drop in the price and waives the profit which might be made in case the price increased. Doing business in this way eliminates all chance of large losses or gains in the fluctuations in prices which take place from the time the farmer is paid for his deliveries until sales are made.

Dealing in futures should be allowed only where actual grain is hedged. Commission firms generally will accept orders for purchases or sales of futures in small quantities, say lots of 1,000 or 2,000 bushels. The commission firm then assembles its various orders and secures trades in larger lots.

INSURANCE OF ELEVATORS.

The practice of insuring against fire is a well-established principle in respect to all property, but carelessness in keeping insurance which is sufficient to cover total loss has proven disastrous in many instances. Owing to the marked fluctuation in the amount of grain on hand during the shipping season, grain elevators particularly are likely to be underinsured. For convenience, it is advisable to insure buildings and contents under separate policies. The policy covering buildings seldom varies in amount during the year, but that covering grain may be subject to change. Some managers in small towns where no insurance agent is stationed have protected their grain stock by insuring for maximum capacity. Others make arrangements with the agent allowing for changes on notice, and thus effect a saving in premiums paid.

DESCRIPTION OF THE OFFICE OF MARKETS AND RURAL ORGANIZATION GRAIN ELEVATOR ACCOUNTING SYSTEM.

As this bulletin is intended to be sufficiently complete to enable an elevator company to install the system as devised by the Office of Markets and Rural Organization, a detailed description of the forms comprising it is essential.

The complete system includes 15 forms, as follows:

Form No. 1—Cash, journal, purchase and sales record.

Form No. 2—Record of grain receipts.

Form No. 3—Record of grain purchases.

- Form No. 4—Record of grain shipments and sales.
- Form No. 5—Record of hedges.
- Form No. 6—Record of sales to arrive.
- Form No. 7—Patronage ledger. (For cooperative elevators.)
- Form No. 8—Grain and merchandise report.
- Form No. 9—Manager's report.
- Form No. 10—Grain check.
- Form No. 11—Scale ticket.
- Form No. 12—Storage ticket.
- Form No. 13—Sales ticket.
- Form No. 14—Cash receipt.
- Form No. 15—Cost analysis.

For convenience of discussion, the description of the foregoing forms will be taken up in respect to the order of their use.

SCALE TICKET.

Form No. 11 (see p. 26) represents the scale ticket adopted under this system, but it is not essential that this exact form should be used, as any scale ticket which records gross, tare, and net, and gross, dockage, and net of the load, together with designations as to the owner and kind of grain, will be satisfactory.

STORAGE TICKET.

In order that all grain may be accounted for properly upon receipt by the elevator, the adoption of the storage ticket as a means of recording bushels and pounds received is strongly recommended. Form No. 12 (see p. 27) represents such a ticket. Upon this ticket are recorded the gross, dockage, and net of all the loads which have been hauled in any one day by a single owner, as previously recorded on scale tickets. Storage tickets should be made up at the close of business each day. Both scale and storage tickets should be numbered consecutively and printed in duplicate.

For convenience in referring to the data entered on storage tickets it is advisable to file the tickets alphabetically under two headings, denoting "stored grain" and "purchased grain." By this system of filing, each patron's sales are kept together and settlement may be effected easily in the case of unsold grain through reference to this file. A small card file containing a card for each patron may be found of assistance in listing numbers of storage tickets and for furnishing other information for checking up the storage-ticket files.

RECORD OF GRAIN RECEIPTS.

After having registered all the receipts of grain on storage tickets under the names of their respective owners, entry should be made on the record of grain receipts (Form No. 2, facing p. 20), where the date, storage-ticket number, the kind, grade, and bushels of grain are noted.

GRAIN CHECK.

In buying the grain a special grain check should be used (Form No. 10; see p. 25), upon which are recorded, in addition to the information usually contained in a check, the number of bushels and kind of grain, together with the purchase price, minus any deductions for storage or accounts receivable, and the resultant amount of the check. Regular checks should be used for all expense and general items.

RECORD OF GRAIN PURCHASES.

These checks, being numbered consecutively, are entered according to number upon the record of grain purchases (Form No. 3, facing p. 20), where the net bushels, storage, and cost of grain are recorded in detail.

RECORD OF GRAIN SHIPMENTS AND SALES.

Shipments from the elevator are recorded upon the record of grain shipments and sales. (Form No. 4, facing p. 20.) Here the date of shipment, the party to whom the grain is consigned, the car number, and shipper's weight are recorded. As soon as the shipment has been sold and the returns have been received the date of sale, price received, destination grade, and proceeds received for the grain are entered.

RECORD OF HEDGES.

A record of hedges (Form No. 5; see p. 21) is a form designed to record the transactions in futures bought and sold. The columns designated "Purchase and sales accounts" are used to record profits or losses on hedges, the "Remarks" column being used to designate the broker through whom the profit or loss is incurred.

RECORD OF SALES TO ARRIVE.

A considerable number of elevators selling grain "to arrive" have no form upon which the transactions can be recorded. Form No. 6 (see p. 21) represents a record of sales to arrive. A brief study of this form will be sufficient to demonstrate its usefulness. It has no part in the accounting system except as a memorandum of shipments made against contracts, but this is important in itself.

MANAGER'S REPORT.

Some elevators which are not doing sufficient business to warrant the hiring of a bookkeeper and in which the elevator manager is unable to keep the books have found it convenient to secure the services of a bookkeeper employed either in a bank or some store of the town in which they are located. For such elevators a manager's report (Form No. 9; see p. 24) has been provided. Upon this report the manager records all the transactions in receipts and purchases of grain and incloses duplicates of sales tickets covering sales of mer-

chandise and of receipts for cash. From this form the bookkeeper, although not employed in the elevator, is able to keep the system of records in a satisfactory manner. The records of disbursements covering incidental items in most cases are controlled by the secretary or treasurer, and the bookkeeper should look to him for records of this type.

PATRONAGE LEDGER.

In a few States cooperative laws have been enacted enabling cooperative organizations to distribute dividends upon a patronage basis, and for elevators operating under this law a patronage ledger has been devised (Form No. 7; see p. 22), upon which are recorded the individual purchases and sales of merchandise under the name of each customer.

GRAIN AND MERCHANDISE REPORT.

At the end of the year, just before balancing the books, an inventory of all merchandise on hand should be taken. Form No. 8, grain and merchandise report (see p. 23), has been provided with suitable headings so that the amounts of grain and merchandise on hand can be recorded. This form serves a valuable purpose in giving the value of net and stored grain on hand at date, from which comparisons can be made showing the amount of stored grain sold.

CASH, JOURNAL, PURCHASE, AND SALES RECORD.

Previously it has been usual to provide a cashbook, journal, and daybook under separate forms in elevator systems. In the system herein described these books, together with a record of purchases, have been incorporated into one form (Form No. 1, facing p. 20), called the cash, journal, purchase, and sales record. As all the forms comprising this system, with the exception of reports and the patronage ledger, are uniform in size and in loose-leaf form, they may be contained in one binder (and the consolidation of four books under one form is a further condensation of the work). In the cash, journal, purchase, and sales record are recorded all regular cashbook entries, such as receipts of money and disbursements through checks, together with all journal entries and records of local sales of merchandise. Purchases of material such as flour, coal, etc., are recorded under "Merchandise purchases," giving pounds and amount.

SALES TICKET.

All the local sales of merchandise are originally entered upon the sales ticket (Form No. 13; see p. 28), and these sales tickets are made up in pads of 50 originals and duplicates, numbered consecutively.

CASH RECEIPT.

All receipts of money other than checks are recorded upon a cash receipt (Form No. 14; see p. 29). It is quite essential that such a receipt be used, as the practice of receiving scrip or coin without making a record of the transaction at the time of receipt often leads to discrepancies which are difficult to account for later.

COST ANALYSIS.

A feature of this system and one upon which considerable emphasis should be laid is a cost analysis (Form No. 15A; see p. 30), by which the relative amounts of grain handled and the actual and relative cost per bushel are determined. Upon this form a determination of the percentage of cost in handling merchandise is also worked out. The value of knowing the ratio of costs in the operation of a business is a well-established essential in many commercial enterprises, and it is no less important to the successful operation of grain elevators.

In conjunction with this system any double-entry, loose-leaf ledger accommodating general accounts and accounts receivable may be used. To be assured of the correctness of entries, it is advisable that a trial balance be taken from the ledger at the end of each month.

INSTRUCTIONS FOR OPERATING THE SYSTEM.

RECORD OF GRAIN RECEIPTS.

The record of grain receipts (Form No. 2, facing p. 20) is a consecutive record of the receipts of grain as shown on the storage tickets. Having entered the storage tickets consecutively for the period of a month, distributing the grain under the proper columns and recording it under gross, dockage, and net, in bushels and pounds, we may at the end of the month total this form to arrive at the total grain receipts for the period. The totals of the record of grain receipts are then carried to the grain report opposite the words "Receipts this period." As the business progresses from month to month, each month's total should be kept separate; and, at the same time, a total should be drawn down, including the current month and the previous months of the current year. This total is also carried to the grain report opposite the words "Gross on hand." Under this system all grain is considered as theoretically stored regardless of whether it is purchased at the time of delivery or actually held in storage. This method is followed because it insures the proper accounting for every bushel of grain which comes into the elevator.

RECORD OF GRAIN PURCHASES.

The record of grain purchases (Form No. 3, facing p. 20) is a record of the net bushels and value of the grain purchased, together with storage which has accrued on the grain up to the time of purchase.

Both the bushels and value of all grain recorded on this form should be totaled on dates to agree with the totals of the record of grain receipts. Like the record of grain receipts, the record of grain purchases should be totaled monthly. The totals showing the amount purchased for the year are carried to the grain report opposite "Gross purchased." The total amount of all checks issued for grain in any month should be carried to the cash, journal, purchase, and sales record and there entered in the "bank withdrawals" column in one amount. The total cost of the various grains is then carried to the debit of the "grain accounts" in the "general ledger" column of the same form, this constituting a consolidated cash entry for all the transactions in grain purchases for the month. Where storage charges are represented, they should be credited to the "storage account" in the "general ledger" column, and in such cases the cost of grain should equal the amount of the check plus the storage charges, because the storage charges are deducted from the grain cost in order to arrive at the amount of the check.

RECORD OF GRAIN SHIPMENTS AND SALES.

The record of grain shipments and sales (Form No. 4, facing p. 20) carries a record of all cars shipped and the net returns from each shipment. The proceeds from each variety of grain should be totaled and posted at the end of the month to the credit of "grain accounts" in the general ledger. The items in the "net proceeds" column should be posted to the debit of the grain commission accounts represented in the "shipped to" column. The monthly totals of bushels from this form should be carried to the grain report opposite "Shipments and sales." In the operation of this form it will be found that some of the shipments for any month will be still standing out as grain in transit at the end of the month. Before beginning a new month, the 1st of April, for instance, it would be necessary to make an entry for the month of March as follows: "Total March returns on February shipments"; opposite this would be set down in total the net returns of all February shipments which had been received during March. In order to avoid confusion, however, reference should be made to February entries for posting to the individual "commission accounts." By this method the total returns on all grain will have been posted to the proper "commission accounts" by individual postings. Although we post only totals to the credit of the "grain accounts," the total returns on each kind of grain shipped during the previous month and returned during the current month can be added in with the March shipments and returns in order to arrive at the total amount of returns for the month of March. This same method will apply if a car shipped in February should not bring returns until April, as the February entry

would show that the car was still standing out through the month of March.

RECORD OF HEDGES.

A record of hedges (Form No. 5; see p. 21) is essential to the proper hedging of grain, and this account should be kept up to date. On this form columns have been provided giving all the necessary information for keeping the accounting record of grain hedges. Profit or loss on hedges should be posted to the general ledger to the debit or credit of the "commission account" represented and to the debit or credit of "profit and loss on hedges," as the case may be. It may be considered that any profit or loss on hedging could as properly be charged or credited to the grain against which it applies, but, as it is important to know just how much the hedging of grain costs, it is much better to carry a "profit and loss on hedges" account until the end of the year, when this account may be written off to the several grain accounts if desired.

RECORD OF SALES TO ARRIVE.

Under the description of the system (p. 6) will be found sufficient information regarding this form (Form No. 6; see p. 21), for, as it is only an auxiliary record for memorandum use, it has very little to do with the operation of the system.

PATRONAGE LEDGER.

At convenient periods during the year reference should be made to the grain checks and to the sales tickets, and the amount of merchandise recorded thereon, both in purchases and sales, should be posted to the patronage ledger (Form No. 7; see p. 22), under the account of the customer with whom the transaction was held. It is essential only that this material be compiled by the end of the year, so that proper reference may be made to it as the basis for paying patronage dividends. Each customer's account is totaled and the rate of dividend per bushel or per pound is entered in the upper right-hand corner. Using this ledger as a basis, checks for the amount to which each customer is entitled can be made out, and dividends distributed accordingly. This form is intended for use in cooperative elevators.

GRAIN REPORT.

The grain report (Form No. 8; see p. 23) is designed to keep the manager and directorate in close touch with the condition of their grain stock at the end of any month, or, in fact, at any time at which additions of the various entries on the grain forms may be made. Assuming that an elevator starts its current year with a certain balance of grain on hand, as shown by the inventory, at the end of the first month, by adding "receipts this period" to "balance last

report," the result will be "gross on hand." By deducting from this the "shipments and sales," the difference will be the "net on hand." It is always important for a manager to know whether the grain which he has on hand belongs to the elevator in whole or in part, or is partly or entirely stored grain. By subtracting the gross amount of bushels of grain purchased from the gross receipts the total amount stored at date will be shown. Should this be greater than the net on hand, it will indicate that some grain which has been stored has been sold without being purchased from the owner of the grain—in other words, that there has been an amount of stored grain sold. Should the total stored at date be less than the net on hand, then the difference between the two would be the amount of purchased grain on hand.

MERCHANDISE REPORT.

The merchandise report (Form No. 8; see p. 23) serves merely as an inventory, giving the total on hand at the last inventory, purchases, sales, and net on hand, which should agree, allowing for proper deductions or additions, with the actual inventory.

CASH, JOURNAL, PURCHASE, AND SALES RECORD.

The cash, journal, purchase, and sales record (Form No. 1), facing p. 20) differs from ordinary books of first entry in that both the debit and credit entries, which are to be posted later to the ledger, are of necessity entered on this form before it can be balanced.

The debit columns of this form are designated as follows:

- Date.
- Folio.
- Cash.
- Bank deposits.
- General ledger.
- Accounts receivable ledger.
- Hard coal (lbs., amount).
- Soft coal (lbs., amount).

There are also provided columns in blank which may be used to suit the convenience and requirements of the individual elevator.

The credit columns comprise the following:

- Check number.
- Folio.
- Bank withdrawals.
- General ledger.
- Accounts receivable ledger.
- Sales ticket number.
- Hard coal (lbs., amount).
- Soft coal (lbs., amount).

There are also blank columns to be used as desired.

A column is provided between the debit and credit sides, marked "Items," in which are written all items and an explanation of them.

DEBIT COLUMNS.

CASH.

In order that an accurate check may be had upon the amount of money received so that an identical amount may be deposited each day, all cash receipts of whatever nature should be entered in the "cash" column. These entries are footed daily and represent the amount of the deposit and are not carried forward during the month, all deposits being set down in the "bank deposits" column as the deposit is made.

BANK DEPOSITS.

In some instances where drafts are drawn directly against commission companies by the bank the money is not received at the elevator, and in such cases the deposit of drafts may be made directly into the "bank deposits" column. In this way the "bank deposits" column would include the total receipts at the elevator plus all receipts of drafts at the bank, and the total of this column carried forward during the month should equal the sum of the deposits in the bank pass book.

GENERAL LEDGER.

The "general ledger" column is provided for entry of all items to accounts in the general ledger for which no special columns are provided, and postings should be made in detail from this column to accounts in the general ledger.

ACCOUNTS RECEIVABLE LEDGER.

The accounts receivable ledger carries items for all local accounts receivable, and items in this column are posted in detail to accounts in the accounts receivable ledger.

MERCHANDISE PURCHASES.

Under the heading "Merchandise purchases" will be found columns designated "hard coal," "soft coal," etc., in pounds and amounts. All purchases of merchandise of this character are entered in their proper columns under this heading, and the totals only are posted at the end of the month to their respective accounts in the general ledger.

CREDIT COLUMNS.

The "check number" column accommodates the numbers of all checks drawn for expense and general accounts other than grain checks. The "bank withdrawals" column records the amounts of these checks. In this column is also entered the total of the grain

checks drawn during the month. The "general ledger" and "accounts receivable" columns serve the same purposes on the credit as were explained on the debit side.

LOCAL SALES OF MERCHANDISE AND GRAIN.

As all the sale tickets are numbered consecutively, their numbers are listed in the "sales ticket number" column, and the merchandise in pounds and amount is entered in the proper column to the credit of the account to which it belongs, such as "hard coal," "soft coal," "flour," etc. These columns are totaled at the end of the month and the totals only are posted to the accounts in the general ledger. Only the items which are posted from the general ledger, accounts receivable ledger, and the miscellaneous columns are listed in detail, all other columns, both debit and credit, being posted as totals. At the beginning of the month the first entry to be made on this form is "cash balance," and this should be set down in the "bank deposits" column as an amount carried forward. Because of the fact that every debit has a corresponding credit, the two sides of this form should always be in balance, but the fact that we have carried forward the cash balance, which appears on one side only, must be taken into consideration. In order that the form should foot and prove correctly, it should always be out of balance by the exact amount of the cash entry at the beginning of the month.

THE LEDGER.

The ledger should be divided into two general divisions—one carrying general accounts and the other accounts receivable—and may be designated under the headings "General ledger" and "Accounts receivable ledger." In the general ledger will be found such accounts as: (1) Cash, which is the monthly balance as shown by the cashbook; (2) "accounts receivable control" account, to which are posted debit and credit totals in the "accounts receivable" columns in the cash, journal, purchase, and sales record, the individual items having been posted previously to the accounts receivable ledger. This account serves as a proof of the correctness of such individual postings. (3) Bills receivable, including all promissory notes, time notes, bills of exchange, or acceptances receivable.

It has been the practice in some elevator accounting systems to show a subdivision of expense in the journal, but the small number of items of this character is much better taken care of through a subdivision of the ledger accounts. An ordinary ledger page may be ruled by the bookkeeper into seven or eight columns, and, as entries to expense in most cases are debit items, no credit columns need be provided. When credits occur they should be posted in red ink and deducted in the addition of the items in the column. The

several columns of the expense account may be headed "Salaries;" "Telephone, telegraph, and electric light;" "Taxes;" "Gasoline;" "Repairs;" and "Miscellaneous," or similar headings suitable to the nature of the expenses incurred.

An account should be provided showing the capital stock outstanding or the portion of the net capital which is used or is available for the working of the business.

Separate accounts should be opened for each kind of grain handled, showing the amount and value of grain purchased on the debit, and the amount and value of grain sold on the credit. At the end of the year, by crediting these accounts with the inventory of the kind of grain specified, the net profit on each kind of grain may be determined. In the case of local sales of grain, it is advisable to open separate accounts so that a clear record may be kept of the amount of grain sold locally, as well as in car lots. These local sales accounts should be closed into the general grain accounts at the end of the year.

During the course of a shipping season a considerable number of claims will arise against railroads for losses of grain in transit. Two accounts should be opened to accommodate this condition: A debit account—claims against railroads for leakage in transit, and a credit account—loss and recovery on grain leakage in transit. These accounts operate after the following manner: When a car is reported short a certain number of bushels under that recorded by the elevator's automatic scale, a charge is put through against the railroad responsible in the first-named account, and a corresponding credit is carried to the latter account. When recovery is received by remittance from the railroad company, the company is credited with the amount of the check. If the check does not cover the full amount of the claim, and no further action is to be taken looking toward its collection, then a journal entry for the remainder should be passed, crediting the account of the railroad in the claims account and debiting loss and recovery on grain leakage in transit. This latter account constitutes an income account and may be written off direct to profit and loss; or if the composition of the account is known, the specific items applying to certain kinds of grain may be credited to the grain accounts.

The following entries in the cash, journal, purchase, and sales record will serve to illustrate the method of accounting for loss and recovery on grain leakage in transit. When the grain is reported lost, the first entry to be made is as follows:

Debit claims (B. & M. Railroad).....	25.00
Credit loss and recovery on grain leakage in transit.....	25.00

After negotiations with the railroad, assume that settlement by an allowance of \$15.00 is received by check. Entry would then be

made of the check showing "Cash debit \$15.00," and "B. & M. Railroad credit \$15.00." This leaves a credit of \$25 to the account for loss and recovery on grain leakage in transit, and a debit to the railroad of \$10.

Considering that the transaction has been definitely settled, and that no further recovery can be made, the following journal entry should be passed:

Debit loss and recovery on grain leakage in transit.....	10.00	
Credit claims B. & M. Railroad.....		10.00

This simply closes the railroad account, and leaves a balance in the loss and recovery on grain leakage in transit representing the true amount of recovery.

THE COST ANALYSIS.

The cost analysis (Form No. 15A; see p. 30) has been provided to furnish information affecting the unit and relative cost of handling grain and merchandise. The method of operation is as follows:

Opposite "Bushels of grain handled" should be set down, first, the total of all grain taken into the elevator, this amount being extended under the different kinds of grain as shown by the footings of the record of grain receipts, the total grain taken in being 100 per cent. The relative percentage of each kind of grain is then set down opposite the per cent mark under the column designated. On the same line should be added the value of coal and merchandise sales.

After taking out an amount which would seem to be sufficient for the selling of merchandise, the different kinds of expense applying generally to all kinds of grain and merchandise, such as salary, insurance, interest, power, and repairs, are then prorated according to the grain percentages. This amount will be, necessarily, more or less of an estimate, but a manager, by keeping account of the time spent on coal and merchandise sales in the space of a month, can arrive at a fair basis for the division of salaries. Insurance, interest, repairs, and miscellaneous, relating to merchandise, are contained in a few items and can be easily ascertained.

Such items as "Power, operating" apply only to grain. "Corn shelling—direct labor" includes only that labor which has been procured especially for corn shelling, and would not include the manager's or assistant manager's time, as their wages are prorated under "Salaries." Car cooperage should be distributed according to the amounts of grain received, except in cases where an account has been kept in the ledger showing the exact amount of cooperage against each kind of grain.

After having prorated the different expense items, the addition of these gives the gross expense. Returns from storage and returns from dockage sold are then set down under the kinds of grain which

have furnished these returns, and subtracted. Any returns from cobs sold are subtracted from cob corn. The net expense is then ascertained from these subtractions.

The net unit expense is determined by dividing the amount of expense by the number of bushels handled. Since in the operation of an elevator there are other items of expense which are more or less fixed, and not within the control of the manager, it is necessary to take these into account as a further consideration in arriving at the total cost of operation.

Bad debts in most cases will be prorated between sales of coal and sales of other merchandise.

Depreciation should be distributed against the elevator on the same basis as other charges after having deducted a proper amount for depreciation of coal sheds, warehouses, etc.

Shrinkage and scale loss should be distributed according to the amount of loss on each commodity as shown in the ledger accounts. Other losses and charges, which will include such losses as uncollected claims against railroads for leakage in transit, therefore, will be directly chargeable against the kind of grain or merchandise upon which the loss occurred.

After having prorated the above charges, addition should be made of these amounts to the net expense, and this will give the total cost of operation. The total cost of operation being 100 per cent, the per cent of cost of operation on each kind of grain and merchandise will be determined as being the relative percentage of each to the total. The net unit cost of operation is determined by dividing the amount of costs of operation by the number of bushels handled in the case of grain or by dividing the amount of cost of operation by the value of the goods sold when determining the net unit cost of operation for merchandise. The net unit cost of operation would be in terms of cents and decimals of a cent per bushel on grain, and in the case of sales of coal and other merchandise, it would be represented by a certain percentage, as, for instance, 6 per cent of the gross sales.

BALANCING CASH WITH THE BANK.

To determine the correctness of the cash transactions for the month the following method will be found simple and adequate:

(1) Determine whether the "bank deposits" column agrees with the bank pass book as to individual deposits. Be sure that it is correctly footed.

(2) Sort the returned vouchers, arranging them consecutively. Compare them with the entries in the "bank withdrawals" column and ascertain which, if any, are missing. List the numbers and amounts of all outstanding checks for the next month's reference. Outstanding checks may be listed either on an adding-machine tape

or by writing them into the cashbook. The difference between the "bank deposits" and "bank withdrawals" columns, plus the total of outstanding checks, should equal the balance as shown in the bank pass book. No error, however small, should be ignored in balancing cash with the bank.

RESERVE ACCOUNTS.

RESERVE FOR DEPRECIATION ACCOUNT.

In order to show the true condition of the plant a reserve for depreciation account is essential. To this account should be credited annually a certain percentage of the money invested in the plant, and an equal amount should be written off profit and loss.¹

RESERVE FOR BAD DEBTS ACCOUNT.

During the operation of a business where credit is given to a large number of customers there is likely to be a loss on account of uncollectible debts. This amount may be small one year and large another. For that reason it is well to set aside a sufficient amount of capital from the yearly profits to offset such losses. To effect this, "reserve for bad debts" should be credited and "profit and loss" debited with an amount which experience would dictate is sufficient to take care of the uncollectible debts of the company.

While many elevator companies make a practice of furnishing supplies to members and others on credit, all supplies, if possible, should be handled on a strictly cash basis. Any system of extending unprotected credit requires a large capital and often results in considerable loss.

RESERVE FOR SINKING FUND.

In some States, notably South Dakota, where the cooperative law is in operation, a statutory regulation requires that a certain percentage of the capital invested be set aside each year in a reserve for sinking fund, so that the company will be in a position to retire its capital stock at the end of a given period. Companies operating under such conditions should set up a reserve for sinking fund in accordance with the requirements of their State laws.

Where the custom of hedging grain prevails, an account should be opened designated "profit and loss on hedging." To this should be debited or credited the losses or gains incident to the hedging of grain, the opposite entry being made to the commission account handling the business.

¹ For further explanation of reserve for depreciation see U. S. Department of Agriculture Bulletin No. 178, "Cooperative Organization Business Methods."

To determine the profit and loss for the year, all income accounts should be credited and all expense accounts debited to this account. When the amount of profit has been ascertained, dividends may be declared and paid, and the remainder transferred to the surplus account.

After the books have been closed for the year, any errors discovered affecting the previous year's business should be entered in the account affected and carried to the opposite side of the surplus account, the profit and loss account being reserved for the current year's business.

The individual needs and the peculiar conditions surrounding elevators in different parts of the United States may require other accounts besides those discussed above, and if such is the case, accounts covering these special requirements may be opened along the same general lines as those previously discussed.

The following balance sheet is submitted as a guide in the arrangement of assets and liabilities. Other asset and liability accounts may appear on the books of an elevator and in such case should be included.

STATEMENT.

BALANCE SHEET, YEAR ENDING.....

ASSETS.

Cash.....		\$287. 50
Accounts receivable.....	\$3, 208. 00	
Less reserve for bad debts.....	400. 00	
		2, 808. 00
Notes receivable.....		325. 00
Plant and real estate.....	9, 500. 00	
Less reserve for depreciation.....	1, 300. 00	
		8, 200. 00
Grain commission accounts.....		860. 00
Inventory:		
Wheat.....	1, 458. 00	
Corn.....	395. 00	
Oats.....	536. 00	
Rye.....	28. 00	
Barley.....	106. 50	
Hard coal.....	281. 00	
Soft coal.....	354. 00	
Other merchandise (supplies).....	2, 976. 70	
		6, 135. 20
		18, 615. 70

LIABILITIES.

Accounts payable.....	\$76. 55
Notes payable.....	4, 200. 00
Capital paid in.....	8, 950. 00
Surplus.....	4, 589. 15
	18, 615. 70

UPPLY ACCOUNTS SETTLED WITH GRAIN.

When requests are received from patrons to deduct from the amount due for grain sold the amount which they may owe the company for supplies purchased, two grain checks should be issued. The first check should contain the total number of bushels and kind of grain being purchased, together with the balance due the patron after deducting the amount of his account from the full value of the grain.

A second check should then be made without reference to bushels of grain, and marked "For a/c receivable," in the full amount deducted from the previous check. This check is then indorsed over to the elevator by the patron and both checks are entered in the record of grain purchases, the first check going to the patron and the second being deposited to the account of the elevator as cash received. By this means both sides of the transaction have been carried out through the only proper medium of settling accounts, *which is cash*.

For the convenience of those interested in the system described in this bulletin and for those who desire to have the system printed, the Office of Markets and Rural Organization has provided printer's copy of the several forms for free distribution.

All elevators installing the system of accounts may refer to this office any questions regarding its installation or operation.

A sectional post transfer binder has been found convenient and adequate for binding the accounting forms. The standard size is, length over all, $15\frac{1}{2}$ inches, width $10\frac{1}{2}$ inches, posts five-sixteenth inch in diameter and 7 inches from center to center.

CONCLUSION.

The foregoing pages outline very briefly certain information regarding operating grain elevators, and in particular describe the methods used in operating a system of grain-elevator accounting devised to accommodate the various requirements in primary elevators throughout the United States. The adoption of a uniform system of accounting for primary elevators should be of benefit both to the companies and to the men employed by them as managers, but the simple keeping of the records is not sufficient. To obtain benefits commensurate with the opportunities open in this field the manager and directors of the elevators possessing such an accounting system should make use of all the information which it is able to furnish. In order that the management of the elevator may be fully advised, not only as to the condition of the business, but as to the economic advantage of the method of doing business which is being pursued, it is advisable that in every case proper attention should be paid to ascertaining the costs as provided for in the "cost analysis" included with this sys-

tem. If the information thus obtained is made available to the stockholders and other interested parties, and they are thereby assured that the business of the elevator is being handled in a competent manner and that details and statistics regarding it can be furnished at any time, it will tend to strengthen the financial position of the company with those who extend credit to elevators during the season of crop movements.

In some of the forms that follow, sample entries are inserted in italics. These entries do not represent actual transactions; they are given merely to show how the forms are to be used.

Markets and Rural Org

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Office of Markets and Rural Organization, Grain System Form No. 1.

25749°—Bull. 362—16. (To face page 20.) No. 1.

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Office of Markets and Rural Organization, Grain System Form No. 2

Totals carried to the Grain Report.

If desired, additional grades under "Wheat" can be included, extra columns being provided if necessary.

All items carried in bushels, fractional bushels in pounds.

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[illegible]

bushels, fractional bushels in pounds.

Date.

Shelled co

<i>1914</i>	Proceeds.	Grade.	Grade 2.	Grade.	Grade.
<i>Dec.</i>					
"					
"					
"					
"					
"					
			1,328		

provided if necessary.

RECORD OF GRAIN PURCHASES.

Office of Markets and Rural Organization, Grain System Form No. 3.

Date.	Check No.	Storage ticket No.	Price.	Amount.	Wheat.						Durum.			Barley.			Oats.			Rye.			Flax.			Corn on cob.			Shelled corn.													
					No. 1.	No. 2.	No. 3.	No. 4.	Reject.	Storage.	Cost.	Net.	Storage.	Cost.	Net.	Storage.	Cost.	Net.	Storage.	Cost.	Net.	Storage.	Cost.	Net.	Storage.	Cost.	Grade.	Grade.	Cost.	Grade.	Grade 2.	Grade 3.	Grade 4.	Grade.	Grade.	Cost.						
1914. Dec.	1	603	887	1.07	83.45		78				83 45																															
"	1	604	891	.57	59.85																98		69 85																			
"	3	605	839	1.05	123.10			123			123 10																															
"	4	606	895	1.00	101.00				101		101 00																															
"	6	607	898	1.00	63.60				63 30		63 60																															
"	7	608	898	1.10	61.00																		45		61 00																	
"	7	609	888	1.12	71.80	85					71 80																															
"	7	610	890	1.10	86.80		88				86 80																															
"	8	611	1004	.48	138.00									237 22		138 00																										
"	8	613	1008	.49	61.45									105		61 45																										
"	8	613	1010	1.10	174.20								123		173 20																											
"	8	614	1005	.41	133.80													226 12		133 80																						
"	8	615	1009	1.16	67.85	80					67 85																															
"	10	616	1014	.69	588.85																																388 5					
"	10	617	1016	.60	374.20																															673 20						
"	29	618	1016	.68	506.00																															506 60						
"	29	619	1017	.67	652.00																															652 00						
"	30	620	1018	.69	805.40																															805 40						
"	31	621	1019	.69	533.40																															533 40						
				6,010.25	124	106 00	122	164 30			612 60	125		173 20	359 22	169 45	326 12		153 80	98 00		69 85	45 00		61 00											2,639 00	745 00	2,078 00				3,779 44
				✓	X	X	X	X			✓	X		✓	X		✓	X		✓	X		✓	X		✓									X	X	X				✓	

✓=Carried to cash journal.

X=Carried to grain report.

If desired, additional grades under "wheat" can be included, extra columns being provided if necessary.

All items carried in bushels, fractional bushels in pounds.

RECORD OF GRAIN SHIPMENTS AND SALES.

Office of Markets and Rural Organization, Grain System Form No. 4.

Date.	Shipped to—	Car No.	Weight.	Date sold.	Price.	Net proceeds.	Folio.	Wheat.						Durum.				Barley.		Oats.		Rye.				Flax.				Shelled corn.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
								Gross.	Dkg.	No. 1.	No. 2.	No. 3.		Proceeds.	Gross.	Dkg.	Net.	Proceeds.	Net.	Proceeds.	Net.	Proceeds.	Gross.	Dockage.	Net.	Proceeds.	Gross.	Dkg.	Net.	Proceeds.	Grade.	Grade 2.	Grade.	Grade.	Grade.	Grade.	Grade.	Proceeds.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
1914.	Lipary & Co.	N. P. 8912	1,200	1914. Dec. 15	1.00	1,245 25	✓	1,210	23		1,187			1,245 25																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

Net proceeds to be debited to grain dealers, and proceeds of each variety of grain to be credited to grain accounts in general ledger, posting to be made direct.
Amount of bushels to be carried to grain report.

If desired, additional grades under "Wheat" can be included, extra columns being provided if necessary.
All items carried in bushels, fractional bushels in pounds.

RECORD OF HEDGES.

Office of Markets and Rural Organization, Grain System Form No. 5.

Futures bought.						P. & S. accounts.				Futures sold.						Remarks.		
Date.	Bushels.	Market.	Bought from.	Month.	Kind.	Price.	Dr.	Cr.	Folio.	Date.	Bushels.	Market.	Sold to.	Month.	Kind.		Price.	
1914. Dec. 6	1,000	Mpls.	W. C. M. Co...	May..	2 wht..	109		18	50	J. 1.	Dec. 16	1,000	Mpls.	Dal- rymple.	May..	2 wht..	1.11	Dr. Hankin- son, 18.50.
Dec. 22	2,000	"	Hankinson....	"	3 "	108												

RECORD OF SALES TO ARRIVE.

Office of Markets and Rural Organization, Grain System Form No. 6.

Date.	Bushels.	Kind.	Grade.	Price.	Delivery date.	Sold to—	Cars applied.	Shippers' weight.	Date shipped.	Date received.	Desti- nation grade.	Desti- nation weight.	Remarks.
1914. Dec. 1	3,000	Wht. corn.	3	64	1915. Jan. 10	Dipsey & Co., Chicago.	A. 96542.....	1,456	1914. Dec.	12	3	1,445—	
Dec. 15	5,000	Yel. corn..	4	58	Febry. 1	Beach, Wickem Grain Co., Peo- ria.	A. 89625..... T. P. W. 9685... T. P. W. 5462... T. P. W. 8625...	1,250 2708 1,600 1,200 1,320 4120	" Dec. 1915. Jan. "	23 30 10 23	3 3 3 4 4	1,254— 1,600— 1,600— 1,310— 1,310—	Premium 1¢.

PATRONAGE LEDGER.

Office of Markets and Rural Organization Grain System Form No. 7.

Rate, 3¢ per bu.
Rate, 1¢ per lb.Name: *James Goodhue.*

Sales.										Purchases.				
Check No.	Wheat.	Durum.	Barley.	Oats.	Rye.	Flax.	Corn.	Live-stock.	Sales No.	Hard coal.	Soft coal.	Flour.	Grain.	
603	78 —	—	—	—	—	—	—	—	186	24 50	—	—	—	
609	65 —	—	—	—	—	—	—	—	187	12 80	—	—	—	
610	88 —	—	—	—	—	—	—	—	199	14 10	—	—	—	
611	—	—	286 70	—	—	—	—	—	325	—	24 12	—	—	
614	201 —	—	286 70	326 12 328 12	—	—	—	—	403	—	14 80	—	—	
	—	—	—	—	—	—	—	—	409	—	22 10	—	—	
	—	—	—	—	—	—	—	—	512	31 40	25 50 86 52	—	—	

This form is intended for use in primary elevators distributing profits on a patronage basis.

WAREHOUSE SCALE TICKET.

Office of Markets and Rural Organization, Grain System Form No. 11.

No., 191

..... Co.

At

This ticket is not a storage ticket and is not negotiable. It must be exchanged on day of issue for a lawful storage ticket or cash check.

Owner

Driver..... On..... Off.....

Load of

Grade..... Dockage Lbs.

Signed Agent.

Exchanged for Check No., Storage Ticket No.

POUNDS.			BUSHELS.		
Gross.	Tare.	Net.	Gross.	Dockage.	Net.
.....					
.....					
.....					

STORAGE TICKET.

Office of Markets and Rural Organization, Grain System Form No. 12.

Scale ticket No.	Gross.	Tare.	Net.	No.
				 ELEVATOR COMPANY.
				At....., 191.....
				Received of.....
				Bushels..... Grade..... Dock..... Grain.....
				which amount, kind, and grade of grain will be delivered to the holder of this receipt, or his order, upon
				surrender thereof, subject to the conditions and charges stated on the back of this receipt.
				bu.,.....lbs. gross.
				bu.,.....lbs., dockage.
				bu.,.....lbs., net.
				 ELEVATOR COMPANY,
				Per

On the back of this form should be printed the rates of storage and the conditions affecting storage of grain as provided by laws in the State in which the elevator is situated.

Office of Markets and Rural Organization, Grain System Form No. 13.

No.

SALES TICKET

Of

At

Sold to Date

HARD COAL.

Gross.....		
Tare.....		
Net.....		
Total hard coal.....		

SOFT COAL.

Gross.....		
Tare.....		
Net.....		
Total soft coal.....		

MISCELLANEOUS.

.....		
.....		
.....		
Total miscellaneous.....		
Total sales.....		

ELEVATOR COMPANY OF

Office of Markets and Rural Organization. Grain System Form No. 15A.

COST ANALYSIS.

Year ending....., 191

	Total.	Wheat.	Durum.	Barley.	Oats.	Rye.	Flax.	Cob corn.	Shelled corn.	Sales coal.	Sales, other merchandise.
	100%.	33.2%.	21.0%.	9.5%.	8.5%.	.7%.	.5%.	.6%.	26.6%.	Value.	Value.
Bushels of grain handled.....	380965	196400	80192	35400	31633	2468	1240	2000	101632	2248	4386
Salaries.....	2200	693	438	194	173	14	6	12	555	43	66
Insurance.....	725	199	126	55	49	4	1	3	159	49	75
Interest.....	180	69	37	16	14	1	54	1	47	88	12
Power, operating.....	226	80	47	21	18	1	68	1	55	60	33
Corn shelling—direct labor.....	4	75	63	31	18	1	59	4	80	10	00
Repairs.....	475	143	93	41	37	3	1	2	63	118	90
Cooperage, cars.....	125	41	26	11	10	88	37	75	33	25	00
Miscellaneous.....	785	245	155	68	61	5	2	4	196	84	33
Gross expense.....	4722	1453	925	410	365	30	13	31	1172	74	192
Returns from storage.....	108	26	20	30	7	50	22	25	1172	74	23
Returns from dockage sold.....	345	30	211	32	135	98	2	50			
Returns from cobs sold.....	2	50									
Net expense.....	4266	1302	771	379	338	30	13	28	1172	74	192
Net unit expense.....		.009	.009	.010	.011	.012	.010	.014	.011	4.8%.	4.5%.
Bad debts.....	150									72	45
Depreciation.....	325	99	63	27	24	2	90	1	79	80	77
Shrinkage and scale loss.....	432	50	76	12	27	1	80		110	40	00
Other losses and charges.....	12	40	12	40	27	80				100	00
Total cost of operation.....	5185	1421	910	420	411	31	14	30	1362	94	269
Per cent of total cost of operation.....	100%	27.4%	17.6%	8.1%	7.9%	.6%	.8%	.6%	26.3%	6.0%	5.2%
Net unit cost of operation.....		.011	.011	.012	.013	.013	.011	.015	.013	11.0%	6.5%



BULLETIN No. 363

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER.

May 8, 1916.

THE PINK CORN-WORM:

AN INSECT DESTRUCTIVE TO CORN IN THE CRIB.

By F. H. CHITTENDEN, *In Charge of Truck Crop and Stored Product Insect Investigations.*

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INTRODUCTION.

For nearly three-fourths of a century the larva of a small moth (*Batrachedra rileyi* Wals.), commonly known as the pink corn-worm (fig. 1), has been found in corn in the field and in store as well as in blasted cotton bolls. It was not, however, until the year 1914 that this species was recognized as a pest. During November and December of that year complaints were made of damage by the pink corn-worm to corn in cribs. The number of complaints was enormous and the damage in Mississippi was so widespread that much alarm was felt in infested districts. The correspondence, which will presently be quoted, shows plainly the extent of the insect's ravages as also the fear that entire crops



FIG. 1.—The pink corn-worm (*Batrachedra rileyi*): Full-grown larva, lateral view. Enlarged. (Original.)

NOTE.—This bulletin points out the increasing menace of this insect, which has never been considered a serious enemy of grain, but now assumes nearly the same importance as the Angoumois grain moth and is much more troublesome than the European grain moth. It also recommends methods of control. It will prove of interest to farmers in the region extending from South Carolina westward to central Texas, southward to southern Texas, and northward to Arkansas and Tennessee.

of corn in the principal regions infested might be lost. While the insect confined its attacks largely to Mississippi, it was also observed in injurious numbers in Arkansas, Alabama, Texas, and Louisiana.

Singularly, the species was not described until the year 1882, when Lord Walsingham gave it the name of *Batrachedra rileyi*, but it now assumes nearly the same importance as the Angoumois grain moth¹ and is much more troublesome now than the European grain moth.² The species sufficiently resembles the latter to have been mistaken for it by Glover and others, and its work has been compared to that of the former. In reality it bears some resemblance to both species in appearance and habits.

The pink corn-worm was first brought to the writer's attention in ripening ears of corn from Texas in 1894 (Chittenden, 1897).³ From the fact that the larvæ first seen were feeding on the husks and the species was not then identified as feeding naturally on the kernels of corn, it was for convenience called the corn-husk moth, and this name might have been retained had not the insect developed later into a destructive grain-feeding species. The names pink corn-worm, pink worm, and red corn-worm are now in general use in the South.

NATURE OF INJURY.

In material received from Baton Rouge, La., and Beeville, Tex., in 1895, the little rose-colored larvæ were noticed by the writer chiefly between the husks, which were fresh and succulent, and on these they were feeding. A few moths were afterwards reared from the husked ear. The Texas sending afforded a fair opportunity for the study of the work of the species. One undeveloped ear harbored numbers of the larvæ which had gnawed into every part of it from the outer husk to the dwarfed ear within.

The injured grains when examined individually have somewhat the appearance of being infested by the Indian-meal moth (*Plodia interpunctella* Hbn.) but not by the Angoumois grain moth. The larvæ evidently begin to feed on the grains while the latter are still "in the milk" or very soon afterwards, beginning at their insertion and working outward toward the crown. The embryo and surrounding parts are hollowed out and the seed envelope is often eaten away about the base or "tip" of the seed. An astonishing amount of frass is developed which is neither eaten a second time nor packed tightly within the kernel, as is evidently the case with the Angoumois moth larva, but the particles, being loosely joined by webbing, fill the interstices between the kernels. (Pl. I.) Usually a single larva inhabits a kernel but frequently the interior of a grain is completely devoured, so that the only part remaining is the thin outer integument inclosing a varying amount of accumulated frass. Doubtless this is the work

¹ *Sitotroga cerealella* Zell.

² *Tinea granella* L.

³ See Bibliography, p. 19.

of more than one caterpillar. It will be noted that the caterpillar does not confine itself, as does the Angoumois moth, to the kernel or any part of it, but attacks seed, husk, and cob alike.

While no positive statement can be made as to the cause of the sudden increase of the pink corn-worm, it may, perhaps, be due to the fact that cotton is not cultivated on so large a scale or so universally as in the past, and possibly it may be due to the destruction of the bolls by plowing them under as a remedy against the boll weevil. These practices would naturally have the effect of driving the moths to deposit their eggs on corn, and this acquired taste of the larvæ might in time be transmitted to their descendants. There can be no doubt that when corn is left too long in the field the ears are more easily penetrated by the insects. Often, too, if they are permitted to remain there over long they become moist, and if stored in this condition injury by the pink corn-worm and other insects is greatly hastened. Still another practice favors the multiplication of the moth, namely, storing corn too long in the husk. The layers of husks just under the outer sheath are frequently badly eaten at about the middle, only the longitudinal veins being rejected. On one fully developed ear nearly every kernel was infested and the ear was so completely enveloped in frass and webbing as to be useless for any purpose. Every ear in which this species was found lodged had been first attacked by the corn-ear worm (*Heliothis obsoleta* Fab.). (Pl. I.)

DESCRIPTION.

THE MOTH.

Batrachedra rileyi belongs to the same lepidopterous superfamily¹ as the Angoumois and European grain moths, but to a different family.² From either of the others this species may be easily distinguished by its smaller size and by its remarkably slender hindwings and their correspondingly long fringes. The forewings are banded and feebly mottled with yellow, reddish-brown, and black. The antennæ are white, annulated with fuscous, and the legs are banded with fuscous. (See fig. 2.)

The wings measure, when expanded from tip to tip, a little less than half an inch (9–11 mm.).

The moths are very active on their feet and when at rest fold their forewings closely together with their tips "cocked up" after the manner of many other tineids and related moths.

Following is the original description by Walsingham:³

Head chestnut-brown; palpi widely divergent, whitish, with an oblique pale brown mark on each side near the end of the second joint, and two or three brownish

¹ Superfamily Tineina.

² Family Elachistidae.

³ Walsingham, Lord.—Notes on Tineidae of North America. *In* Trans. Amer. Ent. Soc., v. 10, p. 198–199, 1882.

spots on the sides of the apical joint. Antennæ with white and fuscous annulations; the basal joint elongate, chestnut brown. Fore-wings chestnut-brown, slightly shaded with fuscous towards the costal margin; a whitish ochreous streak at the base of the dorsal margin, followed by two or three other smaller ones along the dorsal margin (in some specimens these are obsolete); above the dorsal margin are two oblique whitish ochreous streaks, the first before the middle, the second before the anal angle. A similar streak from the costal margin immediately before the apex is outwardly margined by a streak of black scales, the apex and apical margin being also black; there is also a faint fuscous streak running downwards through the cilia below the apex. On the cell are two elongate patches of black scales, one immediately before the middle of the wing, the other halfway between this and the base. Fringes grey, with a slight yellowish tinge. Hind wings pale greyish. Hind tibiæ greyish white, outwardly fuscous; hind tarsi whitish, with a wide fuscous band followed by two fuscous spots on their outer sides. Expanse 11 millim.

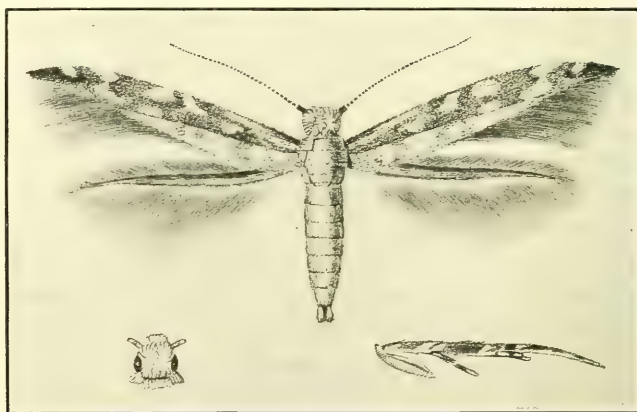


FIG. 2.—The pink corn-worm: Moth, showing head covered with scales; below, at left, head showing eyes at side; below, at right, hind leg. Moth much enlarged, head and leg more enlarged. (Original.)

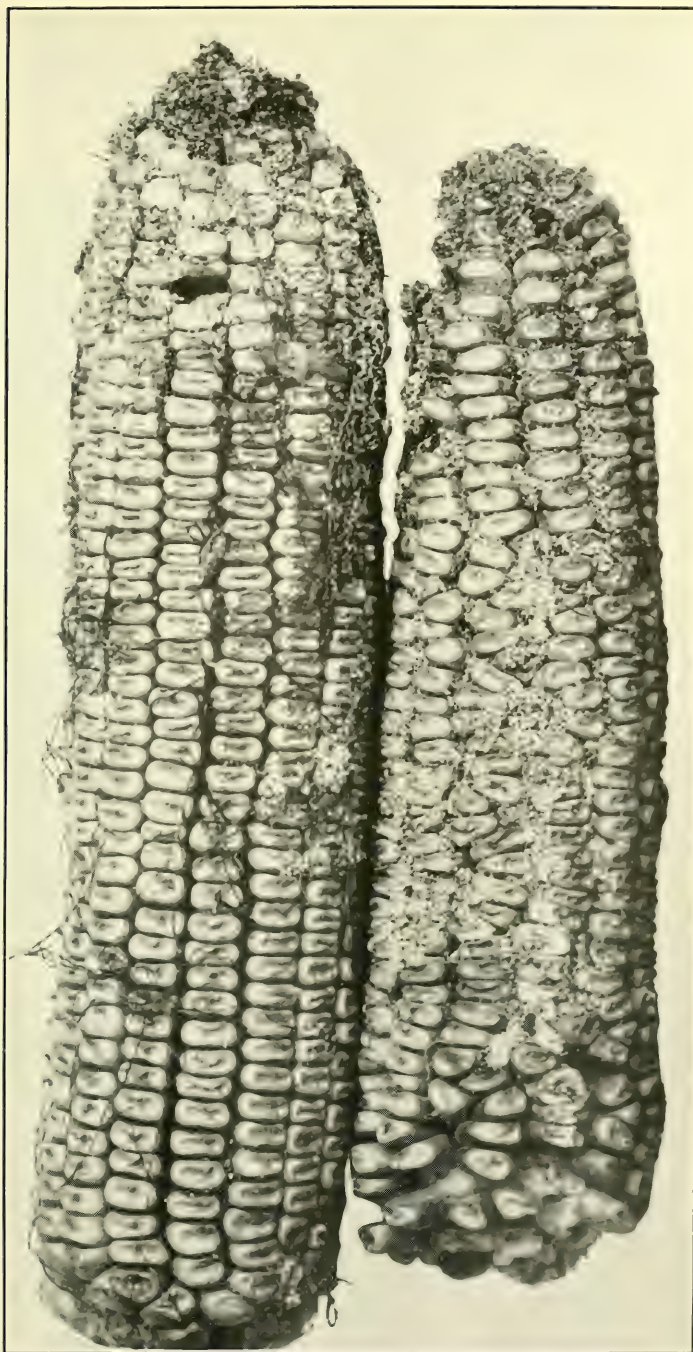
THE EGG.

The eggs of this species resemble considerably those of the Angoumois grain moth (*Sitotroga cerealella*). They have been found deposited on dry corn husks and in such locations are much flattened on the surface, differing in this respect from those of *Sitotroga*. The egg may be described as follows:

Flattened oval; widest near the middle; truncate at one end and narrowed at the other, with the surface strongly wrinkled, forming coarse, irregular, ridgelike longitudinal lines. As would naturally be expected in a species so much smaller than the Angoumois moth the egg is much smaller, and instead of being red it is pearly white throughout with a perceptible iridescence.

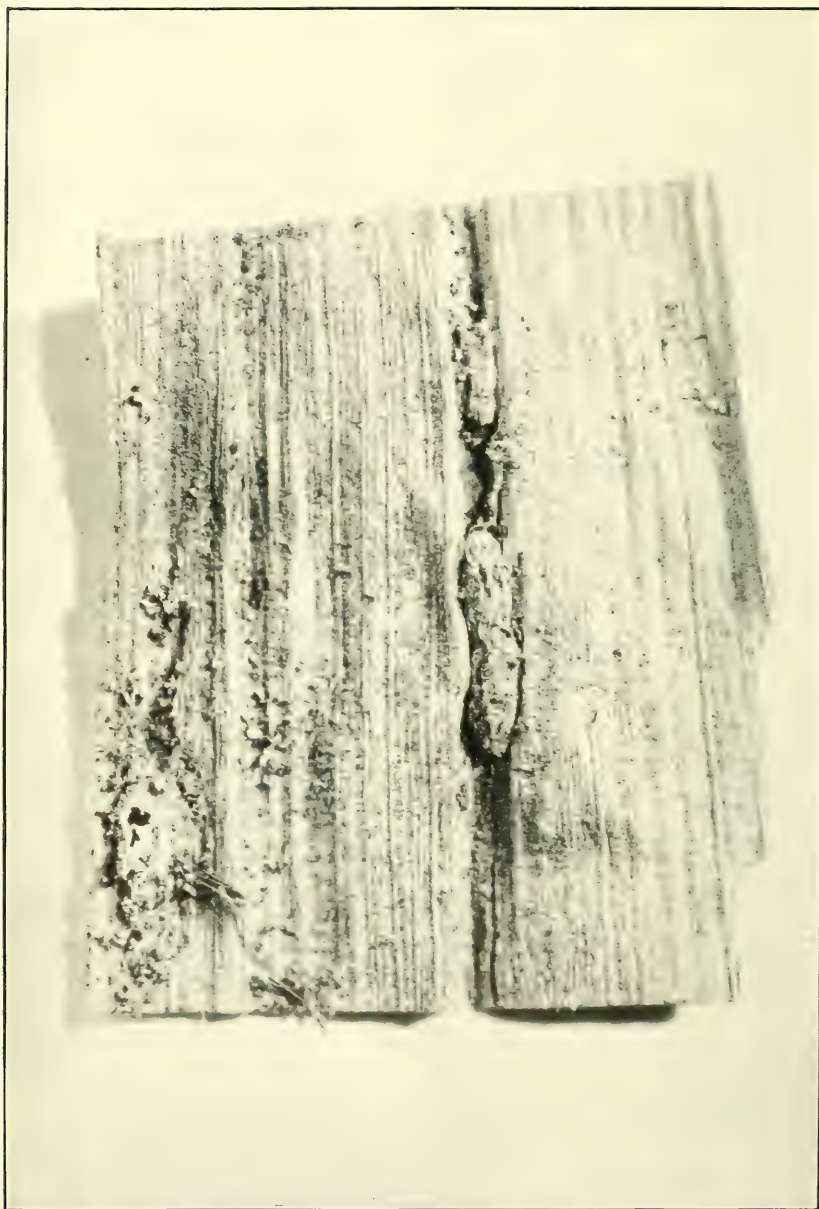
Measurement: Length, 0.4 mm.; width, 0.1 mm.

The eggs are deposited singly or in groups up to three or four. Since they are nearly colorless, not pinkish like those of the Angoumois moth, they are quite difficult to locate with the unaided eye. The egg is illustrated by figures 3 and 4.



WORK OF THE CORN-EAR WORM AND THE PINK CORN-WORM.

Corn ears showing primary injury by corn-ear worm (*Heliothis obsoleta*) at top and additional injury by pink corn-worm (*Batrachedra rileyi*), especially on right ear. (Original.)



COCOON OF THE PINK CORN-WORM ON SECTION OF DRY CORN HUSK, SHOWING A PUPA NEAR TOP AND TWO OVERLAPPING NEAR MIDDLE; ALSO LOCATION OF ONE OR TWO OTHERS AT LEFT. (ORIGINAL.)

THE YOUNG LARVA.

The larva when first hatched is nearly white, but soon becomes pinkish. The head and thoracic plate are darker. It is at this time about 1 mm. in length and quite slender.

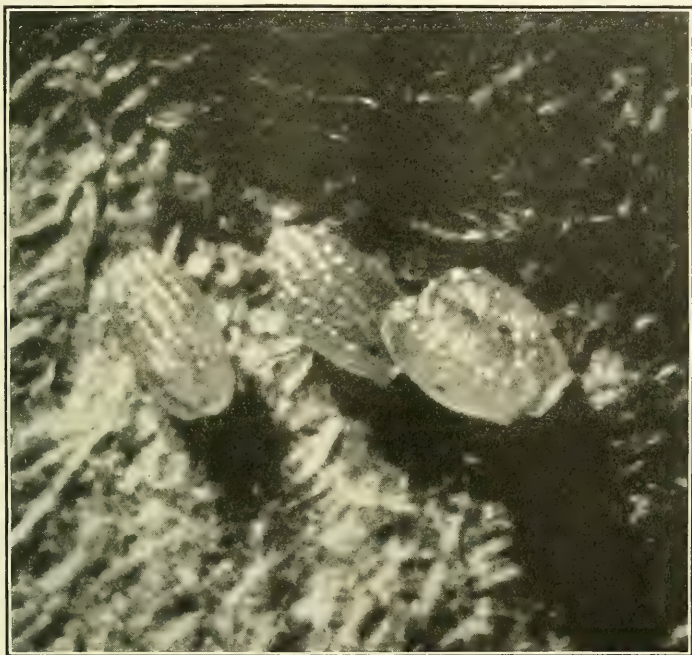


FIG. 3.—The pink corn-worm: Eggs, highly magnified. (Original.)

THE FULL-GROWN LARVA.

When full grown the larva of this species bears some resemblance to that of the Indian-meal moth (*Plodia interpunctella*). It is, however, considerably smaller and more slender, and is somewhat flattened by comparison. It may be described as follows:



FIG. 4.—The pink corn-worm: Egg, highly magnified. (Original.)

When fully extended it is about eight times as long as wide. Head quite narrow, in contour nearly identical with that of *Plodia*; of the same pale brown color, with sutures well marked, and appendages and mouth-parts still darker. Thoracic plate nearly one-third wider than head, well divided at middle; light brown dorsally and dark brown at sides. Thorax and dorsum sparsely covered with concolorous piliferous tubercles with inconspicuous hairs. Body entirely pale carneous or pinkish; lower surface showing slight carneous tint in first two thoracic joints and along the sides. Anal plate quite small, about the same color as the head. Legs whitish and rather short. Prolegs consisting of five pairs. Length, 8 mm.; width, 1.2 mm.

The full-grown larva is illustrated in figures 1 and 5.

The arrangement or pattern of the pink color is shown in figure 5. It appears to be distinctive.

THE PUPA.

Somewhat robust, about three times as long as wide; head subtruncately rounded at apex; eyes large, black, passing under the basal joints of antennæ, showing plainly at the sides and from the back; wing-cases and antennal cases reaching nearly to penultimate segment; segments well-defined, last segment with rounded area near middle and terminating with several short, delicate bristles curved at extreme apices like minute hooks; color yellowish brown.

Length, about 4.5 mm.; width, 1.5 mm.

Figure 6 shows the ventral view of the pupa at the left and the ventral view in outline at the right.

THE COCOON.

The larva spins rather copiously and when fully mature it makes a cocoon of silk, coated somewhat irregularly on the outer surface with frass and other accumulations. A cocoon before the writer measures 7 mm. in length and 2.8 mm. in width, being subcylindrical and a little larger at the end where the head rests than at the anal end. The cocoons vary considerably in appearance, some being much flattened as shown in Plate II. The one described was deposited on a dry husk and partakes of the faded gray color of the latter.

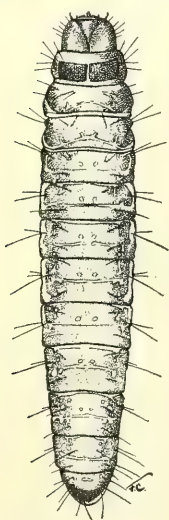


FIG. 5.—The pink cornworm: Full-grown larva, dorsal view. Enlarged. (Original.)

DISTRIBUTION.

As has already been stated, this species has thus far been found most abundantly in Mississippi but it inhabits all of the States bordering on the Gulf, as also Arkansas, Tennessee, South Carolina, and Georgia. (Fig. 7.) The southernmost point from which it has been reported is Brownsville, Tex., and it is without doubt present in Mexico. The most northern point is in Tennessee. The species is also found in Hawaii and may be native to the Orient, although we have no record of this. The probabilities are that it is not indigenous to Hawaii but may be to Mexico and our Gulf States.

RECORDS OF INJURY.

The reports which follow are not verbatim but they give a very good idea of the nature of injury in different localities and the opinions of practical growers in regard to losses and danger of future injuries.

INJURY DURING 1914.

November 9, 1914, Mr. W. B. Thomasson, jr., Murfreesboro, Ark., sent many ears of old, musty corn, badly injured by the pink corn-

worm as evidenced by abundant webbed-up excrement. He stated that this species, together with the rice weevil, whose presence was shown by characteristic holes in the corn, was at that time destroying all corn in the crib throughout the country, and that if not prevented from so doing the "worms" would destroy all the corn there.

November 28, Mr. R. W. Harned, entomologist, Mississippi Agricultural and Mechanical College, Agricultural College, Miss., sent specimens of corn which were badly infested with this small pink larva. He wrote:

During the past few weeks we have received dozens of complaints from correspondents in regard to the damage caused by these insects. Some claim that practically all of their corn has been consumed by these small "pink worms." Many who claim to have raised corn for years state that they have never before seen anything of this kind. Although I have received dozens of samples of these insects I have so far been able to rear only one adult or moth, and I have noticed only one kind of larva. They are these little pink larvæ that make webs wherever they go. In some cases they eat the entire grains.

In order to furnish you with an idea as to what farmers in Mississippi think about the pink corn-worm I quote from a few letters on file as they come to me:

Mr. W. M. Taylor, Kilmichael, Miss., wrote, "I am sending specimens of small pink worms which are doing considerable damage in this section to stored corn."

George M. Bates, Union, Miss., wrote, "There is a small worm of a reddish color eating up the corn in the bins. I want to know the origin of this worm and what remedy to use to stop its work."

J. H. Rice, Sardis, Miss., wrote, "I have inspected and find a small red worm in every ear of corn. * * * It seems to be eating the corn severely. I have looked at several other places around Sardis and find them in every place."

C. S. Tindall, Winona, Miss., wrote, "I am sending some pink worms found in my corn. Every ear has from 1 to 50 worms and the corn that has been in the barn longest seems worst infested. The recent cold weather did not kill them on the corn in the fields."

Jason N. McColl, McColl, Miss., wrote, "Am inclosing small box of worms which are very numerous in everyone's corn in this section."

L. P. Bell, West, Miss., wrote, "We find a small pink-colored worm in our corn. They enter the grain at the little end next to the cob and eat up the grains. Some farmers report that cribs of corn have been destroyed in places. Investigation shows that they are in all cribs of corn in more or less quantities and the farmers are becoming very uneasy for fear the entire corn crop will be devoured. They appear to be worse in damaged corn but are found in sound ears too."

G. C. Tucker, Tyro, Miss., wrote * * * "I am sending an ear of corn. You will see how it is damaged. My entire crop is infested with this insect; in fact, it is almost half ruined. I want to crib my corn at once but am afraid to do so in the condition it is in."

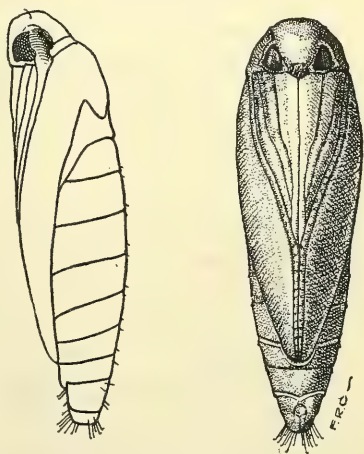


Fig. 6.—The pink corn-worm: Pupa, ventral view at right, lateral view at left. Enlarged. (Original.)

M. D. Doss, Dossville, Miss., wrote, "I am sending an ear of corn which has some kind of a worm in it that is eating it up. It is a very small pink-looking worm. I have heard a great many people in this community talking about this worm in their corn. Please tell me what it is and how to get rid of the same."

W. H. Ellard, Kosciusko, Miss., wrote, "Would like to know what to do for my corn. I find a small pink worm about the size of a large needle. They seem to work from top to butt. Would like to know what to do to destroy them at once. I have 600 bushels infested this way."

W. L. Synnott, Embry, Miss., wrote, "The corn in this section is infested with a small pink worm which seems to be doing considerable damage."

J. B. Harris, Stewart, Miss., wrote * * * "I am sending you an ear of corn infested with a worm that I am informed is destroying entire cribs of corn in some sections. Practically all of the corn in this section is more or less infested."



FIG. 7.—Map showing distribution of the pink corn-worm in the United States.
(Original.)

L. L. Wilson, Ethel, Miss., wrote, "There is a little red worm eating my corn—doing a lot of damage."

J. W. Johnson, Rio, Miss., wrote, "I am sending you specimens of worms that are eating up everybody's corn in this country."

On December 8, Mr. Harned again wrote in regard to this species, furnishing the following notes concerning correspondence during November:

* * * "From the large number of letters that I have received this pest is undoubtedly most serious in Attala County and the counties immediately joining it. There can be no doubt that this insect is causing an immense amount of damage in this State at the present time. The farmers have become excited about it and many have called me over the long-distance telephone and every mail brings in letters in

regard to it. We find the ears infested in the fields as well as in the cribs. I am sure that they work on sound cobs.

Mr. L. P. Bell, West, Miss., whose letter has just been quoted in brief, wrote:

Investigation shows that they are in all cribs of corn * * * the farmers are becoming uneasy about the crop. They appear to be worst in damaged corn but are found in sound ears too.

Mr. Thos. H. Jones, who has been working under the writer's direction, makes practically the same statement, and Mr. J. B. Garrett, Assistant Director of the North Louisiana Experiment Station, Calhoun, La., under date of November 24, 1915, wrote as follows:

It would appear from my observation, which of course is rather limited, that the "pink corn-worm" is found in ears of corn most frequently where they have been previously injured by bollworms, birds, etc., *but I have seen them in ears which were perfectly sound and showed no signs of other injury.*

We must accept this as the truth in spite of the fact that the writer and several others have never seen any infested ear of corn which was not first attacked, if ever so lightly, at the tip of the husk by the bollworm or some other insect, giving ample opportunity for the moth of this species to deposit her eggs.

On December 2 Mr. W. H. Horne wrote from Laurel, Miss., that his community was thrown into considerable confusion by the discovery of a little pink corn-worm which was doing damage to many cribs of corn. As the pest seemed to be comparatively new he was desirous of any information that would enable the growers to stem its ravages. He desired also a personal visit from an agent of the department.

The Bureau of Entomology received later, through Hon. T. U. Sisson, a communication from Mr. W. B. Rainey, Hesterville, Miss., stating that there was a little worm known as the "pink worm" in that country eating the corn after it was cribbed. Information in regard to some remedy was urgently requested. The statement that the insect formed a web at the little end of the ear, and from there proceeded downward eating and webbing, left no doubt that this was the species in question.

On December 5 Mr. R. P. Wright, wrote from Carthage, Miss., amply describing this insect, saying that it threatened to destroy the corn in that vicinity, and that numbers were imbedded in almost every ear of corn, which they ate most voraciously.

INJURY DURING 1915.

During January, 1915, ears of corn showing average infestation of the pink corn-worm were received from Mr. K. H. Diggs, Lexington, Miss.; there were three varieties of corn taken from five different cribs. The corn was planted between April 5 and May 10, and har-

vested in October and November. Mr. Diggs reported that he found the worst damage in immature or imperfect ears where the bollworm or birds had attacked the ear.

During the last days of December, and on January 1, this species was reared from different lots of corn received from Mississippi. One of these localities is Sardis; another is Batesville. The material was received about November 19.

Twenty ears of corn were received on January 7 from Mr. Thos. H. Jones, of the Bureau of Entomology, Baton Rouge, La.; all were imperfect, every ear having been injured and much stunted by the corn-ear worm (*Heliothis obsoleta*). The larval forms of *Batrachedra rileyi* were crawling over the husks of the corn in great numbers, as also on the inside of the bags, seeking a suitable spot for pupation. There were approximately 400 larvæ of various sizes. The larvæ worked on the underside of the grain, especially in the decaying grains or parts of the ears, but the actual damage resulting in this instance was not great. Pupæ were also found in various places—in the husks, beneath the hollow grain, in the cob, and among the castings on the ear. Mr. Jones wrote as follows:

Larvæ were common in undeveloped and poorly formed ears of yellow flint corn in a field at Baton Rouge, on January 2. The valuable ears had been pulled from the stalks in the fall, the stalks at present being dead and brown and, for the most part, still standing. The larvæ were found beneath the husk, working on the surface of the cob among the remains of the kernels, many of which have never matured.

January 29, Mr. J. J. W. Smith, Waterford, Marshall County, Miss., sent three ears of corn badly infested with the little worms. They were described as doing much damage to the corn.

They go from one end to the other in the heart of the corn. Shucking the corn out is the best and safest way to save the corn. Cold weather does not seem to have any effect on them while the shuck is on the corn. But when the corn is shucked and knocked about it helps the corn and does not give the worms such a good chance.

February 1, Mr. W. T. McDonald, Bailey, Miss., sent specimens working in corn ears injured by the corn-ear worm, with the statement—

we attribute the heavy infestation of the worms this season to the extreme dry weather while the corn was making. I find on my place that the corn worst hurt by the drought is worst infested by the "worms." * * * I have never had any experience with the pest prior to the present season, and I may be in error.

Similar complaints were also received of injury to corn from various other localities, as follows: Brownsville, Tex., reported by M. M. High; Lawrence, Union, Saultillo, Harris, Louin, Battlefield, Chunky, Coila, Beach, and Thyatira, Miss.; Fayette, Ala., and Scott, Ark. The insect has been reported by Prof. J. M. Beal, Agricultural College, Miss., to have attacked Kafir corn. During November of 1915 complaint of injury by this species was made at Quitman, Miss.

January 16, 1915, Mr. C. E. Smith collected in the field at Baton Rouge, La., and sent to the writer several cobs of corn in the husk. The cobs were poorly formed, most of them having few developed grains, and they showed old work of the corn stalk-borer (*Diatraea saccharalis* Fab.) and of the corn-ear worm. A number of adults of the rice weevil (*Calandra oryza* L.) were present in the husks, and adults of *Cathartus gemellatus* Duv. were abundant in the same situation.

The pink corn-worm was found among the leaves of the husk, in the kernels, and in the cob itself. Larvæ of various sizes were present, but were mostly nearly full-grown, judging from some that were observed in silken cocoons in all locations where larvæ were observed.

It was difficult in this case to estimate how much feeding had been done on the husks, kernels, and cobs by the *Batrachedra* larvæ because of the injury by, and the presence of, other insects. Larvæ of *Cathartus gemellatus* and of *Sitotroga cerealella* were also present and may have caused some injury. It seems, however, that a part of the silk and most of the small pellets are due to the work of the *Batrachedra* larvæ and that some of the cavities in the kernels were due to them.

Messrs. Thos. H. Jones and C. E. Smith found the pink corn-worm in various sizes, some apparently full-grown, working on ears of sweet corn, in company with several other species. In some ears they were working where the husk was still green and in some cases where the husk had begun to dry. The larvæ followed attack by other insects, or where from some other cause a portion of the ear had become exposed as from injury by birds, and "nipping off" of the tips by a horse, etc. In many cases the ears in which they were working were in bad condition, being so injured as to be of little value.

At Baton Rouge, La., on July 24, 1915, moths were placed in a jar containing yellow cornmeal with a piece of sponge moistened in sweetened water, the jar being placed in the insectary. The first moth, coming from eggs laid by moths placed in the jar at this date, was noted on September 30. The time taken for the development would indicate, when compared with the rate of growth on other substances, that cornmeal is not a particularly good food for the larvæ. It will be noted here that it was possible to rear this insect in cornmeal in experiments conducted at Washington. Another point should be made, namely, that infestation in Louisiana has not been anywhere near as severe as in Mississippi, and that most of the corn ears received from the latter State were in exceedingly bad condition.

EARLIER RECORDS.

From correspondents of the Bureau of Entomology we have had this species from Colquitt, Perry, and Atlanta, Ga., and New Orleans, La., in cotton bolls.

In September of 1894 and again in November, 1895, specimens in the several stages, together with ears of corn in which the insect was living, were kindly sent the writer by Mr. E. A. Schwarz, who gathered them in the field at Baton Rouge, La., and Beeville, Tex., respectively.

June 6, 1909, Mr. D. K. McMillan sent some of this species feeding in the seed-heads of sorghum from Kingsville, Tex. About the same time he sent specimens of what he described as "pink larvæ," common under the shuck on corn ears, from Santa Maria, Tex. Later he sent more material from Kingsville, Tex., from which six adults were found on June 25, three on July 10, one on July 12, and more on July 13, 16, and 26. On June 20 he found this species working in corn in the husk at Beeville, Tex. November 9 of the same year the larva was again found in the heads of sorghum.

During 1912 specimens were received from Mr. M. M. High, Bureau of Entomology. On February 16 they were found working on corn. Seven living larvæ were placed in cornmeal and all died in two days.

During 1913 this species was received in dasheens (*Colocasia* sp.) from Mr. R. A. Young, Brooksville, Fla. The adults issued December 3 and continued to issue from the dry corms.

HISTORY AND LITERATURE.

Our early literature bearing on the biology of this moth, if we except line notices and brief mention,¹ is contained in the accounts of Townend Glover. In his first two entomological reports (Glover, 1855, 1856) its habits are described and the insect in its several stages figured. In the first article the species is treated under the name of "grain moth (*Tinea?*)"; in the second as the "corn worm (*Heliothes?*).". Afterwards in his Manuscript Notes from My Journal, or Entomological Index (Glover, 1877) the same writer refers to this species as *Tinea granella*, throwing the responsibility of its previous determination as "*Heliothes?*" upon D. J. B[rown]. He found it in the cornfields of South Carolina and Georgia in September and says: "It infests the cornfields, where it is sheltered by the husks, and burrows between the grains, upon which it feeds, somewhat in the manner of the Angoumois moth, except that the kernels are more irregularly eaten," and that "these worms also appear to attack corn out of the field as well as in." Beyond this statement the writer is not aware that the insect has ever been mentioned as occurring in the granary, but from personal experience several years ago it was learned that it feeds upon the ripened corn and is perfectly capable of living indoors and that it unquestionably does so. Whether it is possible for the species to breed *ab ovo* in stored, i. e.,

¹ In the American Entomologist for May, 1880 (v. 3, p. 129), and again on page 121 of the appendix of the Fourth Report of the United States Entomological Commission, incidental mention is made of this species with the comment that, according to Chambers, it is a new species of *Laverna*.

dry, grain, it was at that time impossible to say. Glover also mentioned the occurrence of the insect in cotton bolls that had previously been pierced by the bollworm or split open by the rot.

In an article on the cowpea-pod weevil (*Chalcodermus aeneus* Boh.) the writer (Chittenden, 1904) mentioned the fact that the holes left in the pods affected by this weevil, which were formed by cracking or otherwise, led to secondary infestation by other insects. Among those reared during that year from cowpea was the species under consideration.

In a paper by Mr. E. S. Tucker published in 1911 (Tucker, 1911) mention of this species is made as follows: "Larvæ of this moth were frequently found in fallen bolls associated with and without *Araecerus fasciculatus* or its work. The larva is supposed to feed on insect remains." Again in the same article Mr. Tucker notes the finding of the same species at Alexandria, La., September 18, 1908, "in cornstalks infested by *Araecerus fasciculatus*, or where the latter had worked and left, and decay had begun," * * * "particularly in rotting, rain-soaked stalks"; the adults maturing in the breeding cage October 22-29. Mr. Tucker also reports that he found it "in green cornstalks, and sometimes in ear tips injured by the corn worm, *Heliothis obsoleta* Fab., at same place, August 2, 1909," and that "Mr. J. D. Mitchell submitted pupal cases taken from *Araecerus* cavities, in cornstalks at Victoria, Tex., March 7, 1909."

In his article on insects which affect the cotton plant, Dr. L. O. Howard (Howard, 1896) mentions this species in connection with its occurrence in young cotton bolls, and states that there was a general belief among planters that the species acts independently of cotton-worm damage. He added:

This statement, however, has not yet been satisfactorily substantiated so far as it refers to the bolls. In the young squares, however, the active little reddish larva of this *Batrachedra* is very often found as unquestionably an original inhabitant, and it undoubtedly frequently causes quite an extensive shedding of the squares. This, however, occurs only in the spring, at a time when there is a surplus of bloom and when many squares can be spared without great reduction of the crop. Later in the season the *Batrachedra* larva is found boring in the unopened flower heads of various weeds.

The following year the writer (Chittenden, 1897) published some notes on this species, identifying Glover's corn-feeding tineid as *Batrachedra rileyi*.

In 1909 Mr. Otto H. Swezey (1909) repeats Walsingham's description and states that the larva was found in Hawaii feeding in various situations, most frequently on dead vegetable matter or refuse substances, and that therefore it was not particularly injurious. The larva was observed feeding beneath leaf-sheaths of dead cane; also in "borered" cane stalks in places where the leaves were dirty and sticky from the attack of aphides or leafhoppers. It was also found working in the tassels and very numerous in sweet-corn ears, feeding

on the "silks," inner husks, pith, and other parts of the cob; also in ears of field corn, eating into the kernels and cobs. At another time he observed it on a large woody twining bean vine, feeding on dying leaves and ripening pods, especially where there was an accumulation of webs and frass, or where other insects had been at work. Among other food plants he mentioned lantana, palm leaves, and the dead leaves of Pandanus, banana, and "various other plants." On banana the larvæ fed in the bunch on the dead or injured fruit and on the skin of the ripened fruit which they sometimes punctured, even eating into the fruit within.

ASSOCIATED INSECTS.

It has already been reported that this species usually follows the attack of the corn-ear worm (*Heliothis obsoleta* Fab. [Pl. I]), which is true of most other forms of stored-grain insects in the South. At about the same time the rice weevil (*Calandra oryza* L.) enters the corn but does not seem to work with the same rapidity as does the species in question. Later, in all probability, another species which is quite common, the square-necked grain beetle (*Cathartus gemellatus* Duv.) enters the ears and causes considerable damage both in the field and in store. This same insect is often found associated with the pink corn-worm in cotton bolls, and breeds in the same. The rice weevil occasionally enters cotton bolls, especially when they are on the ground, but does not breed in them, merely entering them for shelter or for hibernation. The Angoumois grain moth (*Sitotroga cerealella* Zell.) also breeds in corn with the species under consideration but thus far has not been found in many instances. It was observed at Agricultural College, Miss., in a sending dated November 28. The sorghum midge (*Contarinia sorghicola* Coq.) was also found associated with the pink corn-worm in sorghum seed from Brownsville, Tex., collected by A. K. McMillan, Nov. 9, 1909. A common moth ([*Nola*] *Nigetia sorghiella* Riley) was found in the same lot with the sorghum midge and it is probable that in this case the pink corn-worm followed attack of the *Nigetia* moth.

Among other associated insects are the foreign grain beetle (*Cathartus advena* Walt.) and the coffee-bean weevil (*Araecerus fasciculatus* De G.). The former is of comparatively little economic importance, feeding for the most part on stale grain, fruits, and other stored material, being naturally of a scavenging nature. Nevertheless, it has been quite troublesome during the past two years. The latter attacks coffee beans, mace, dried figs, and various other dried articles of commerce, and is also found somewhat commonly in diseased cotton bolls. A small ortalid fly (*Euxesta anonæ* Fab.) was reared January 29, 1914, from dasheen (*Colocasiasp.*) affected with the pink corn-worm. This last species is without doubt a natural feeder on dasheen, but no record of its habits is available.

To show how severe is the injury wrought by the pink corn-worm, an ear of corn which has been infested only about 10 months is shown in Plate III. The larvæ were swarming under the husk, which has been removed to show the extensive webbing and injury to the kernels. For comparison with this is shown another ear of corn (Pl. IV) which was infested originally by the Angoumois grain moth and afterwards by the Indian-meal moth and rice weevil. At the time the photograph was made the Indian-meal moth had escaped, leaving its webbing. The latter ear weighs about twice as much as the former. The ear in Plate III was the best that could be found out of eight infested by the pink corn-worm, while that in Plate IV was picked at random to show the holes made by the Angoumois grain moth in escaping from the kernels and the extensive and peculiar webbing of the Indian-meal moth. In Plate III the pink corn-worm was still working in numbers, but in Plate IV neither of the moths mentioned could be found in any stage. While the ear in Plate IV had been held in store for two years, that in Plate III had been stored only 10 months.

NATURAL ENEMIES.

For some unexplained reason this insect appears to have few natural enemies, only one parasite having been reared. It is more than probable, however, that some predaceous insects, as well as bats and nocturnal birds, attack the moth when in flight in the fields and about the infested cribs. From larvæ received from Mr. E. A. Schwarz in cotton bolls gathered at Virginia Point, Tex., December, 1878, an ichneumon parasite issued March 3, 1879, and was identified as *Pimpla* sp. (U. S. D. A. No. 1041 P.°).

METHODS OF CONTROL.

Assuming that the damage in Mississippi and other States in the South is due largely to increased production of cotton and to the fact that it follows attack by the bollworm, it is suggested that if we could successfully combat the bollworm or corn-ear worm it should have a decided effect in lessening the numbers of pink corn-worm.

The corn should be gathered and husked as soon as possible, and the ears showing infestation by the pink worm should be fumigated immediately or fed to swine or poultry. This would prevent the infestation of other corn in store. Particular attention is called to this method of treatment since in some parts of the South it is customary to gather corn by "snapping" the ears, these afterwards being stored with the husks intact. This practice especially favors the development of certain grain-feeding pests, including the pink corn-worm. Moreover, the closeness of the husks renders successful fumigation by means of carbon bisulphid nearly impossible.

The additional handling incident to the husking process is also of benefit, as many of the larvæ are dislodged thereby, and the husked ears afford little concealment for pupation and for the feeding of the larvæ.

The best ears when dry could be saved to a considerable extent by placing them in an isolated weevil-and-mouse-proof fumigator such as a metal crib, to be made as nearly air-tight as possible.

CARBON BISULPHID.

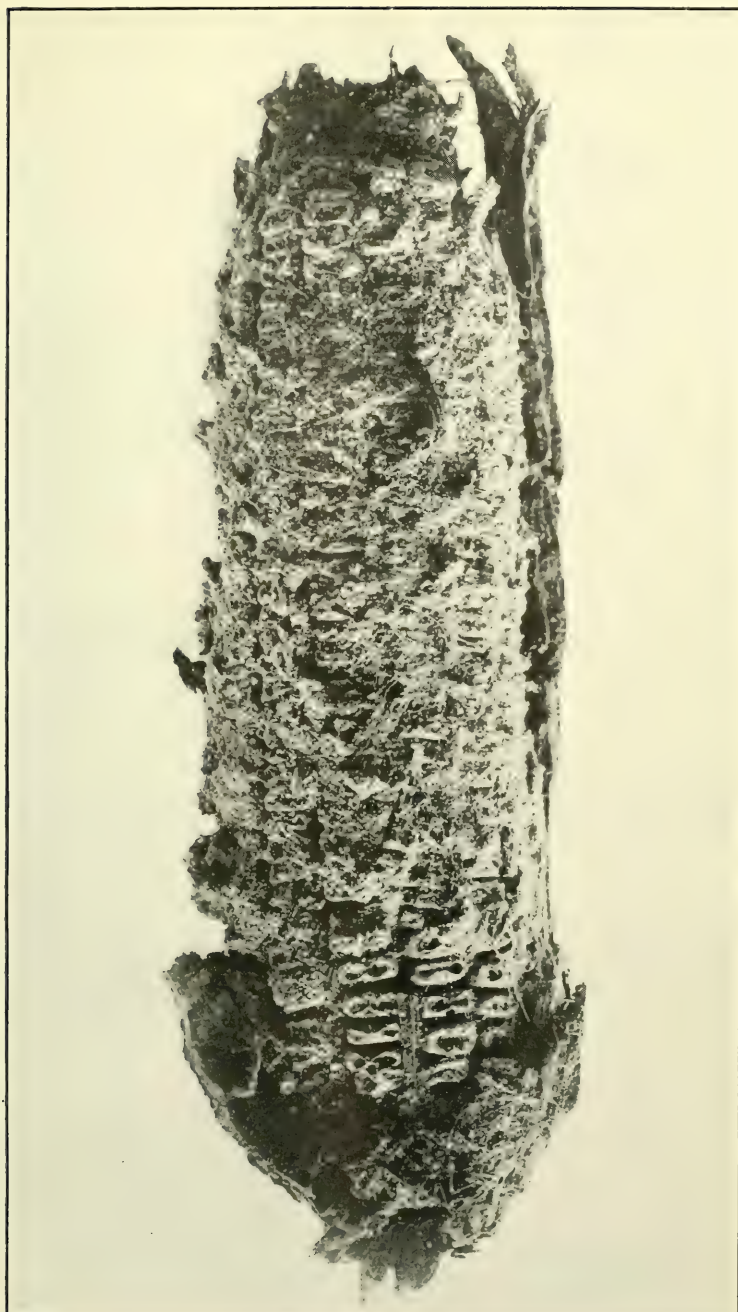
In the South, where the pink corn-worm is so injurious, bisulphid of carbon is the best remedy and has already been used for its control. Carbon bisulphid, or bisulphid of carbon (CS_2), is a heavy liquid, colorless when pure, and is one of the standard chemicals for the control of insects injurious to stored products. Its value lies in the fact that it is extremely volatile, passing into the open air as a heavy gas which settles to the bottom of receptacles in which the liquid is exposed and, by replacing the air, causes suffocation. It is much used against the Angoumois grain moth and various other insects injurious to corn and other cereals. It is less poisonous to human beings than hydrocyanic-acid gas and, while there is danger from fire owing to its inflammability, with a reasonable amount of care this chemical may be cheaply and effectively applied to almost any stored product infested by insects.

It is more effective at a high temperature, 76° to 90° F. proving the best for its use. It is less effective under 70° , and not efficient as low as 50° F.

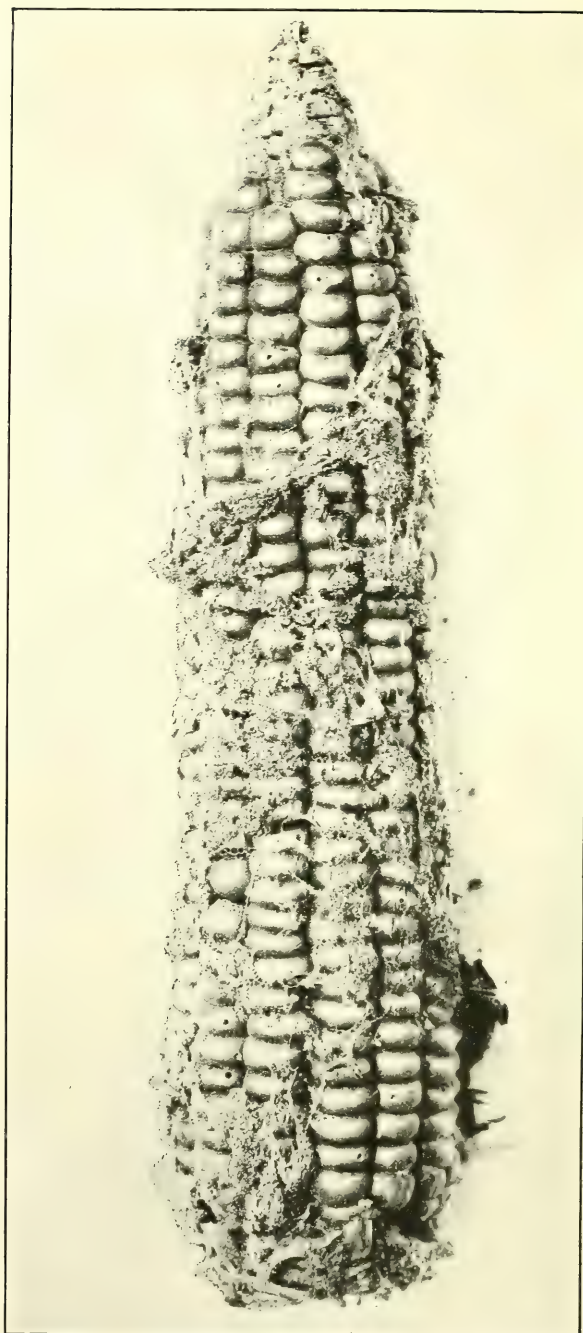
DIRECTIONS FOR USE.

Since carbon bisulphid is extremely volatile, it is best evaporated in flat vessels—milk pans, pie tins, and cheap plates serving this purpose admirably. An average application is 2 or 3 pounds to 1,000 cubic feet of air space, or 1 pound to 100 bushels. Less may be used, but it has been found that in a structure which can not be made positively air-tight it is necessary to use this amount to insure success. The liquid is poured into the evaporators, a half pint or more in each, and, as the gas is heavier than air, the evaporators are then placed in the higher parts of the bin or fumigator. Evaporating pans are frequently set on the top of the grain, allowing the gas to penetrate to the bottom, or, in the case of shelled corn, a perforated tube, such as a drive-well point, may be thrust into the grain and the requisite amount of the liquid poured therein.

When the gas is used in open bins or other receptacles the surface of the grain should be covered with heavy tarpaulin or canvas. The bin should be kept closed as tightly as possible for about 36 hours; this will not destroy the germinating power of the seed. With grains not desired for planting the bins may be allowed to remain closed as long as the gas evaporates.



EAR OF CORN FROM WHICH THE HUSK HAS BEEN REMOVED TO SHOW SEVERE INJURY BY THE PINK CORN-WORM. (ORIGINAL.)



CORN EAR SHOWING INFESTATION BY THE ANGOUMOIS GRAIN
MOTH (*SITOTROGA CEREALELLA*) AND AFTERWARDS BY
THE INDIAN-MEAL MOTH (*PLODIA INTERPUNCTELLA*).
(ORIGINAL.)

The pink corn-worm and associated insect pests which have been mentioned enter the seed of grain in the field, so that treatment is most effective if made as soon as possible after harvest.

In the case of small quantities of seed a tight barrel may be used as a receptacle. One or two ounces of carbon bisulphid may be placed in a small saucer or pie tin upon the top of the grain and the top of the barrel covered with heavy cloths or oilcloth.

In the fumigation of a large building at least two, and preferably three, men should assist in the operation. The building should be tightly closed and the pans or containers for the liquid distributed about the building. Then, as far as possible, the work should be begun in the lower parts of the building, working toward the top. After the cubic capacity of the building and of the separate rooms has been computed, the requisite quantity should be divided among the pans in each room, about one pan to each 100 square feet of floor space being used. After the liquid has been poured into the pan the room should be left at once and the other parts of the building treated in the same manner. While the gas is not immediately fatal, it is well not to inhale too much of it, since nausea and severe headache are likely to result. After the building has been treated in the manner mentioned, exit should be made promptly and the doors tightly closed.

At the end of the period of exposure doors and windows should be opened wide so that the gas may escape. One or two hours should then elapse before work is resumed in the building. A slight odor may still linger in the poorly ventilated corners of rooms but there will be no danger to occupants from the gas, and the odor will gradually disappear with ventilation.

PRECAUTIONS.

Particular attention must be called to the danger from fire due to the presence of carbon bisulphid in the air, and special reference should be made to it in connection with the treatment of buildings.

The danger of bringing a lighted cigar or other lights, such as a lantern, into the presence of the gas must always be borne in mind, since in at least one case an explosion of considerable violence was caused by such carelessness.

The application should always be made in daylight, as no artificial light of any kind is allowable. Even electric lights may not be used, since there is always danger from the sparks caused by turning them on and off. Electric and other motors and steam pipes should be turned off, that no danger may result from the sparks or heat.

Owners of adjoining premises should be warned as to the character of the work that is being done and the need for care if vapor should penetrate their rooms to any extent.

It would be an added measure of safety if a watchman were kept on guard on the premises from the time the application is made until ventilation is complete. It would also be well to place large "DANGER" signs on the doors.

OTHER REMEDIES.

Among other remedial measures storage of corn in large bulk is recommended, since the surface layers of shelled corn or other grain are most exposed to infestation while the lower portions are not so apt to be injured, if at all. The larvæ could penetrate corn in the ear to a considerable depth, but, as their life is short, this is probably seldom done. The moths are unable to do so. Agitation applied to a mass of grain is also destructive to the moths, since they are unable to extricate themselves and perish in the attempt. Cold storage may be employed for valuable seed corn, and naphthalene balls may be used for the same purpose. The most scrupulous cleanliness should always be observed, much injury due to stored grain insects being directly traceable to disregard of this. Old grain and refuse material containing sweepings of grain, dust, dirt, and rubbish in general should not be allowed to accumulate and serve as breeding places for injurious insects.

In conclusion, it should be stated that promptness is absolutely necessary for the control of the pink corn-worm and that bisulphid of carbon can not be profitably used in open cribs, so that if this insect continues its ravages it may be necessary to construct special fumigating buildings and to store the corn in tighter receptacles than the cribs and bins now used.

SUMMARY.

1. The so-called pink corn-worm is not a true worm, but the caterpillar or larva of a minute moth known as *Batrachedra rileyi*.
2. Attack on corn begins in the field and continues after the corn has been stored. When the stored product is husked, the infested ears show injury by accumulations of webbing and frass or excrementitious matter. A careful inspection discloses the "pink worm."
3. The eggs are deposited in the field where the tips of the corn ears are more or less open, due to the attack of the corn-ear worm. After the latter has departed the pink corn-worm continues the injury and by its work makes it easy for other insects and water to enter the ears, which eventually are ruined.
4. From the cob or between the rows of grains the worm penetrates the kernels at the tip or point of attachment, works into the embryo or "germ," which it destroys; then outward to the crown.
5. Unlike the Angoumois grain moth and the rice weevil, which are usually to be found working in the same fields and frequently in

the same ears, this "worm" does not confine itself to the kernel, but attacks kernel, husk, and cob alike.

6. Also, unlike most other grain pests, it appears to be confined among cereals to corn and sorghum, although it attacks, but does not seriously injure, cotton bolls which are more or less open, and some other plants.

7. While thus far it has proved most injurious in Mississippi, it ranges from South Carolina westward to central Texas, southward to tropical Texas, and northward to Arkansas and Tennessee.

8. During the years 1914-15 the pink corn-worm was reported to have occasioned very considerable injury, and much alarm was felt because of its abundance in the regions mentioned. Previously, although known to attack corn, it has never been considered a serious enemy of grain.

9. Naturally it can not be foretold when, if ever, such an outbreak will recur.

10. As a preventive of injury, corn should be left in the field no longer than is absolutely necessary for drying it; the husks should then be removed as soon as possible, the poorest of the infested ears destroyed promptly or fed to swine or poultry, and the best ears fumigated with carbon bisulphid according to the directions given on previous pages.

11. The bins or cribs should be kept scrupulously clean, and should be fumigated before new material is stored in them.

12. Cooperation among corn growers of as large a territory as possible where the species occurs should be secured, that future losses may be prevented.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 364

Contribution from the Forest Service,
HENRY S. GRAVES, Forester



Washington, D. C.

April 15, 1916

FOREST CONSERVATION FOR STATES IN THE
SOUTHERN PINE REGION.

By J. GIRVIN PETERS, *Chief of State Cooperation.*

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THE SITUATION SUMMED UP.

A situation confronts the States of the southern pine region—Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Arkansas, and Missouri—which, unless met and controlled by adequate legislation, threatens seriously to affect their future development and prosperity. The situation arises from the removal of the pine and hardwood forests without proper provision for restocking those cut-over areas, valuable chiefly for the growing of timber, and from the destruction by fire of the young trees and other vegetation on watersheds of important rivers, which carries with it increased erosion, the silting up of stream channels, and danger from floods.

If cutting continues at the present rate without provision being made for new timber crops, southern yellow pine will in the course of time cease to be an important commercial resource of the South. It is now one of the chief sources of wealth, but it is probable that

NOTE.—The bulletin points out the essential elements in the various forest problems that confront the States in the southern pine region, shows how these problems are inter-related, and forms a basis on which may be founded a plan for solving them—matters of great importance to lumbermen, farmers, and all others interested directly or indirectly in the conservation of the timber resources of that region.

the annual cut has already reached the high point. If pine is to continue to play an important part in commerce and industry in the South, steps will have to be taken now to protect cut-over areas from fire and unrestricted grazing, and to manage them in a way to insure continuous production.

Investigations have shown that the removal of the forest ground cover by repeated fires has increased the amount of soil washed into such streams as the James, Roanoke, Wateree, Savannah, Alabama, Pearl, Red, Arkansas, Trinity, Brazos, and Colorado (of Texas). Great sums of money are spent annually in dredging work to remove sand bars from the rivers of this region. Bare ground from which rain runs off as quickly as it falls also increases the danger from floods; and floods in the Southern States have in the past caused millions of dollars damage to property and the loss of many lives. Watershed protection will not of itself prevent floods, but it will lessen their frequency and seriousness; and it will prevent excessive erosion over the whole area covered.

The solution of such problems as these is necessary to the future welfare of the whole community, and experience has demonstrated beyond question that they can be solved satisfactorily only through public action. Adequate forest legislation would involve in each State:

- (1) A nonpartisan department of forestry.
- (2) A technically trained forester as State forester.
- (3) A forest fire protective system.
- (4) Cooperation with private owners and towns in preparing plans for the management of timberlands and woodlots and for commercial and shade tree planting.
- (5) State-owned forests by gift or purchase.
- (6) An adequate appropriation of funds.

Besides the steps just outlined, each State might well make an examination of its own lands (if it possesses any), and withdraw from sale those chiefly valuable for timber production, setting them aside as State forests. Measures might also be taken to restrict the running at large of live stock.

The southern pine States lie in a region especially favorable to the rapid growth of desirable tree species and offer an exceptional opportunity for the practice of forestry. Virginia, North Carolina, and Texas already have adopted forest policies, but their combined yearly appropriations for putting them into effect amount to less than \$20,000.

At the request of each of the States in the southern pine region, except Georgia, and in cooperation with them, the Forest Service

has made studies of their forest conditions and reports have been prepared and, in most cases, published either by the State or by the Service.¹

WHAT THE LUMBER INDUSTRY MEANS TO THE SOUTHERN PINE STATES.

The manufacture of lumber and other timber products ranks first among the industries of Alabama, Arkansas, Mississippi, and Virginia. It ranks second among the industries of Florida, Georgia, Louisiana, and South Carolina, third among those of North Carolina and Texas, and sixth among those of Missouri. Something like 16,000 sawmills operate in these States, and a large number of additional establishments manufacture cooperage stock, veneers, and other forest products. These plants employ some 330,000 persons, or about one-third of all the workers engaged in the various industries. The average annual lumber cut in the region amounts to about 19,500,000,000 board feet, of which approximately three-fourths is yellow pine. Assuming an average value for the lumber of \$14 per thousand feet, the total value of the annual cut would amount to nearly \$275,000,000. About a quarter of this sum represents the value of the stumpage from which the lumber is manufactured; the greater part of the remainder is paid out in the form of wages to residents of the region.

The amount of standing timber in the southern pine region has been estimated by the Bureau of Corporations and the Forest Service as 675,000,000,000 board feet, of which 385,000,000,000 feet is yellow pine, 40,000,000,000 feet cypress, and the remainder principally hardwoods. At the present rate of cutting this amount will last scarcely more than 35 years. Should there remain no commercial bodies of yellow pine or prospect of any, after the present stands are exhausted, the resultant loss to the people of the Southern States in business and wages will be very seriously felt.

The naval-stores industry, which is one of the most important in the South and which depends upon yellow pine as a source of supply

¹ "Forest Conditions in Virginia and Proposed Measures for Forest Protection," by W. W. Ashe, House Doc. No. V, Communication from the Governor, 1910;

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for turpentine and rosin, has an annual output valued at approximately \$30,000,000. This industry, too, must either cease to exist or else move its operations to other portions of the country, unless provision is made now for a future supply of timber suitable for turpentering.

FOREST FIRES.

The chief obstacle in the way of the conservation of the region's timber supply is forest fires. These kill many trees of merchantable size, destroy young trees and seedlings which otherwise would form the basis for new timber crops, consume the ground cover and soil humus, leaving the earth bare and subject to erosion, and sometimes destroy human life.

As long ago as 1879, according to figures gathered for the entire region in the Tenth Census, 729 fires burned more than 5,000,000 acres, causing a money loss in salable products and improvements of \$2,250,000. This estimate was undoubtedly low at the time that it was made, since conditions were not favorable for gathering complete figures.

While no other attempt has been made to obtain figures for the entire region, the present annual loss is unquestionably much greater, since the construction of railroads, the development of lumbering, and the practice of brush burning have gone on steadily. North Carolina is the only State in the southern pine region for which data on the present damage from fire are available. During the five-year period from 1909 to 1913 the average number of fires reported per year in North Carolina was 633; the average area burned about 415,000 acres, and the average loss as follows:

Value of timber destroyed.....	\$160, 000
Value of young growth destroyed.....	204, 000
Value of forest products destroyed.....	218, 000
Value of improvements destroyed.....	66, 000
Total damage.....	\$648, 000
Number of lives lost.....	2
Cost to private individuals to fight fire.....	\$19, 000

Concerning the value of young growth destroyed the State Forester of North Carolina says:

The growing realization of the value of unmerchantable young growth is perhaps the chief reason for the apparently high money loss. Whereas in 1911, the first year any general estimate was placed on destroyed young growth, the loss from this one cause amounted to only 25 per cent of the total damage, in 1912 it comprised 33 per cent, while in 1913 it has increased to 45 per cent of the total estimated damage. An instance of the growing recognition of the destructiveness of woods fires comes from Transylvania County. A farmer there claimed \$300 reduction in the tax valuation of his place because 300

acres had been burnt over. This reduction was granted by the county commissioners. The county therefore lost several dollars in taxes every year from that one fire, besides the much more serious loss sustained by the farmer.

In North Carolina the destruction of mature timber is only a small part of the fire damage, because the usual surface fires, unless occurring late in the spring, do not kill the larger trees. For this reason the value of the reproduction and young growth destroyed necessarily assumes large proportions.

And further concerning the total loss:

The very serious annual loss from forest fires can perhaps best be brought out by a comparison. The average loss from fires in North Carolina for the past five years has been about \$650,000 a year. This is equivalent to a tax levy of 36 cents on the \$100 on all the land in the State, or a tax of 13 cents on the \$100 on all property, real and personal, now listed for taxation. How quickly would this fire tax be done away with if it came in the form of a regular tax levy! Yet the fire tax is paid year after year by the people of North Carolina without a murmur. One or two per cent of the amount lost, if properly spent by the State, would reduce the fire damage one-half the first year, and not only save much valuable property belonging to our citizens, but insure the future well-being of the State.

With the North Carolina figures as a basis, the average yearly damage from forest fires in all of the States of the southern pine region may be estimated as 3,500,000 acres burned over, with a money loss of \$6,500,000. If to this were added the losses from soil deterioration and floods, the damage would be far greater.

Damage to the forests in this region is confined principally to the young growth. This is especially noticeable on the cut-over longleaf pine lands, which are burned over every spring and fall and so kept in a practically barren and waste condition. Except on the bottom lands, damage of this character prevails in all the forests and is generally severe.

Some of the cut-over lands will undoubtedly be devoted to agriculture, but in the meantime fire and erosion are robbing them of valuable chemical and physical elements. Should they be kept in trees as a means of retaining their fertility until demanded for cultivation, their value will certainly be higher than if they are allowed to deteriorate through neglect. This is especially true of the less valuable agricultural areas.

In many places the disposal of cut-over pine lands for farming purposes will go on very slowly. A merchantable crop of longleaf pine trees for pulpwood can be grown naturally in 30 years if protected from fire. Commercial shortleaf and loblolly pines can be grown in even a shorter time. Consequently, a real opportunity is presented of utilizing the cut-over areas profitably while awaiting the time for their agricultural development.

Besides the cut-over lands suitable for agriculture, there are large areas valuable chiefly for the production of timber. Land should,

and will eventually, be put to its most profitable use—real farming land to agriculture, real forest land to timber culture. For the present, however, all land which is not actually under cultivation or needed for pasture purposes should be in timber, as a means of maintaining productiveness and of conserving the fertility of such parts of it as will eventually be put to agricultural use.

The exclusion of fire from cut-over areas will practically insure new stands of timber in place of the old. Little or no planting will be necessary. The abundant reproduction of yellow pine wherever the young growth has escaped the ravages of fire is evidence that yellow pine will reproduce itself naturally if only given a chance.

The protection of cut-over lands from fire will, of course, entail an expenditure, the full burden of which most private owners of timberland will hardly feel themselves in a position to bear on account of the long time element involved in growing future crops of timber. This is the situation in practically all the large forest areas in the United States, and many of the individual States are recognizing the public interest involved by assisting in the protection of such lands. Another and very important reason for State aid in forest fire protection, and one which is especially strong in the southern pine region, is the danger from floods, which is greatly increased by the destruction of the forest cover on the watersheds of streams. Losses from floods along the Southern Appalachian streams alone during the ten years preceding 1908 aggregated more than \$35,000,000.¹ Floods, erosion, and soil washing are together a serious menace to the steady development and continued prosperity of the southern States. Control of forest fires is one means of removing their cause.

Forest fires occur in the southern pine region, because there is little or no public sentiment against them. They are accepted as inevitable and as uncontrollable. This, however, is just the opposite of the truth. Experience elsewhere has demonstrated that most fires can be prevented; with prompt action all fires can be controlled. The problem is largely one of education; public opinion must be focused upon the subject. The fact must be constantly reiterated that forest fires can be prevented with a little care, and that, unless they are prevented, the welfare of every citizen of the State is affected. Education of this kind can only be effectively carried on through organized effort on the part of the State. The value of a protective force patrolling the woods, warning persons against the careless use of fire and securing their good will and cooperation in preventing and extinguishing fires, has been demonstrated over and over again by a prompt and impressive decrease in fire loss in every State where it has been tried. The States in the southern pine region have all

¹ Preliminary Report of the Inland Waterways Commission, 1908, page 522.

passed punitive laws against setting fires. What are needed now are laws providing for the establishment of a protective system and funds to maintain it. Virginia, North Carolina, and Texas have recently enacted such legislation. It will be to the lasting advantage of the other States in the region to follow the example of these three.¹

Closely related to forest fires is the destruction of timber by insects, since the damage done by fire affords entrance for the beetle into the timber, while trees damaged by insects are particularly liable to destruction by fire. Although not generally recognized, insect attacks may cause widespread and serious damage to pine timber in the South. Since 1902 the southern pine beetle has been more or less active in the Southern States from Virginia to Texas, and in some localities has killed a large amount of timber. It is not within the scope of this bulletin to discuss insect depredations, but any State which plans to inaugurate a forest policy should communicate with the Bureau of Entomology, Department of Agriculture, Washington, D. C., for advice regarding the best means of preventing injury to timber from this source.

UNRESTRICTED GRAZING.

Wherever stock is permitted to run at large, it is the general practice to fire the woods once or twice a year in the belief that this improves the forage. Fires set for this purpose cause great damage to the young growth and do not make the grass any better. As a matter of fact, continued burning reduces the vitality of the better grasses, which are then replaced by less desirable ones. More than this, if fires were kept out new grass would actually make better growth, partly as a result of receiving protection from the older grasses; and often a mixture of new and old grass makes much more satisfactory feed for cattle than new grass alone.

Damage to the forest, especially in the longleaf pine region, is caused by hogs devouring pine seeds and tearing up pine seedlings for their tender roots. The amount of such damage, when the whole region is taken into account, is really large and must be reckoned with.

The grazing problem can be solved in large measure by impressing upon the farmers and landowners the fact that in the long run the forage is injured instead of being improved by fire in the woods every year and by making the most of local laws which prohibit stock being run at large. The best and surest means, however, of putting an end to the damage to woods and forage is a State-wide law compelling the inclosure of stock.

¹ Virginia, chap. 195, laws 1914; North Carolina, chap. 243, public laws, 1915; Texas, chap. 141, laws, 1915.

FOREST MANAGEMENT.

With a few exceptions, no attempt is made in the southern pine region to manage private forests for continuous production. Nor is this done in the United States generally. Present economic conditions make necessary the lumbering of the larger holdings on a big scale. This means a large annual cut accompanied by rapid depletion of the merchantable timber supply. Even where curtailment might otherwise be possible, it is frequently prevented by a heavily bonded indebtedness, on which the necessary payments must be made with the proceeds from the annual cut of timber. Nowhere is this more often the case than in the southern pine region. The farmer also often sacrifices his woodlot to meet indebtedness. Yet even where it is possible for the lumberman or farmer to cut his timber only as the market and his personal needs may require, he usually does the cutting without reference to a future crop of timber on the same land.

To meet this problem the States of the southern pine region need to investigate economic conditions in the lumbering and farming districts, with the idea of giving advice to private owners as to how far the practice of forestry may pay in dollars and cents. Assistance should also be offered in the planting of trees on waste areas and in the prairie regions and in shade-tree planting in towns and cities. It is customary for the owner or town to pay the agent's field expenses, while the State pays his salary. All States with forestry departments have provided for work of this character.

STATE-OWNED FORESTS.

Large areas of true forest land should be owned by the State, since it is better able than the private owner to hold the land for continuous timber production and for stream-flow protection. Public ownership, furthermore, guarantees a permanent administration of the properties. The stability of the lumber industry may thus be assured, and with it, steady employment for the wage earner. The educational effect of public forests as demonstration areas is very important and may be productive of excellent results. Public forests can also be used as recreation grounds by the people of the State, and may eventually become an attraction for tourists and pleasure seekers from other parts of the country. They also afford range and breeding ground for game. Through revenue from timber sales and other privileges they should become self supporting. In some cases sufficient revenues should be derived from them to go to the support of other State activities as well.

Nearly every State which has given serious attention to its forest problems has provided for the establishment of publicly owned for-

ests. Those now having State forests are Connecticut, Indiana, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, South Dakota, Vermont, and Wisconsin. The number of State forests is approximately 150 and their aggregate area 3,700,000 acres. New York has 1,800,000 acres, Pennsylvania 1,000,000, Wisconsin 400,000 acres, and Michigan 277,000 acres. At a recent election the people of Minnesota approved an amendment to the constitution permitting the State to set aside as State forests all lands now owned by it which are chiefly valuable for the production of timber, amounting to about a million acres.

Practically all of these State forests have been established through purchase, although in the West some were set aside from lands already owned by the States. New York has spent approximately \$4,075,000 and Pennsylvania \$2,250,000 in buying lands for State forests. Pennsylvania has paid about \$2.25 an acre for the same land, cut over and burned, which it sold years ago, when covered with timber, for about 27 cents an acre. These lands are now estimated to be worth \$6 an acre.

The Federal Government, under the terms of the so-called Weeks law, has also adopted this policy as regards lands situated on the forested watersheds of navigable streams and has appropriated \$11,000,000 for purchases.

It is probable that the States in the southern pine region have disposed of nearly all their timber holdings. Just how much of such land, which can be used most profitably for growing timber, remains in the ownership of the States should be determined as soon as practicable and steps taken to withdraw it from sale and set it aside as State forests. In addition, these States should gradually acquire, through purchase or gift, other bodies of true forest land, especially in regions like the Southern Appalachians, the pine hills, and the Edwards Plateau in Texas. When lands are taken over by a State provision should be made to reimburse the counties and the townships for loss of tax revenue. Some States pay a tax on the same basis as if such lands were privately owned; others pay a fixed charge of a few cents an acre. The Federal Government gives counties in which National Forests are situated 25 per cent of the gross revenues, and an additional 10 per cent is used, in cooperation with the localities concerned, for the construction of public roads.

LEGISLATION.

A consistent and comprehensive forest policy can be carried out only through a forestry department and a State forester. Such departments are urgently needed and earnestly recommended. They have been established in only three States in the southern pine re-

gion—Virginia, North Carolina, and Texas. Louisiana has provided by law for a forestry department under the State Conservation Commission, but for lack of funds it has never been organized. Alabama endeavored to establish a forestry commission, but the law authorizing it was declared unconstitutional on account of an error in the procedure of enactment.

Thirty States have established forestry departments. Some have placed them under departments already established, namely, the board of agriculture in Colorado and Vermont; agricultural experiment station in Connecticut, Kansas, and Ohio; geological survey in North Carolina and Virginia; agricultural and mechanical college in Texas; State school of forestry in North Dakota; State land department in Idaho, Montana, and South Dakota; and forest, fish, and game department in Tennessee and West Virginia. New and separate organizations have been created as forestry boards or commissions by California, Indiana, Kentucky, Maryland, Minnesota, New Hampshire, Oregon, Pennsylvania, and Washington. New Jersey, New York, and Wisconsin have consolidated their forestry departments with so-called allied departments into conservation commissions, and, similarly, Michigan has put the forestry work under a public-domain commission. Maine, Massachusetts, and Rhode Island have given control to a forest commissioner or State forester, who, as in the case of the board or other organization, is directly responsible to the governor or the legislature.

Whatever the character of the organization may be, the best results will be obtained by keeping it free from politics. If a single officer directs it, his tenure of office should be permanent and he should be removable only for cause. If a new and separate board is organized, it should be nonpartisan and the members should receive no compensation other than necessary traveling expenses. The ex officio membership of the board should comprise officials who are removed from politics as far as possible, such as the president of the State University, director of the State forest school or agricultural experiment station, and the State geologist. Appointees to the board might be chosen, as in some States, upon the recommendation of organizations interested in the advancement of forestry in the State, such as conservation, forestry, agricultural, lumbermen's, or timber owners' associations.

The State forester should be chosen solely for his fitness for the position and should be a technically trained forester of experience. If he is to work under the direction of a board he should be appointed by the board.

The forestry department should be authorized especially to organize a forest-fire protective system; to cooperate with private owners and towns; to acquire lands for State forest purposes; and

to make forest investigations. A reasonably adequate appropriation of funds will be required to carry on the work.

As an example of a law which provides for these features may be cited that which was recently passed by the Legislature of Texas. This measure is brief and simple. The Texas Forestry Association was organized by a number of public-spirited citizens especially to do educational work on its behalf, and the press throughout the State gave very generously of space in both news and editorial columns for the same purpose. The law follows:

An act authorizing the board of directors of the Agricultural and Mechanical College to appoint a State forester, prescribing his qualifications, duties, and salary, providing for a system of forest protection, management, and replacement, and declaring an emergency.

Be it enacted by the Legislature of the State of Texas:

SECTION 1. That there shall be appointed by the board of directors of the Agricultural and Mechanical College of Texas a State forester, who shall be a technically trained forester of not less than two years' experience in professional forestry work. His compensation shall be fixed by said board at not to exceed \$3,000 per annum, and he shall be allowed reasonable traveling and field expenses incurred in the performance of his official duties. He shall, under the general supervision of said board, have direction of all forest interests and all matters pertaining to forestry within the jurisdiction of the State. He shall appoint, subject to the approval and confirmation of said board, such assistants and employees as may be necessary in executing the duties of his office and the purposes of said board, the compensation of such assistants and employees to be fixed by the said board. He shall take such action as may be deemed necessary by said board to prevent and extinguish forest fires, shall enforce all laws pertaining to the protection of forest and woodlands, and prosecute for any violation of such laws; collect data relative to forest conditions, and to cooperate with landowners as described in section 2 of this act. He shall prepare for said board annually a report on the progress and condition of State forestry work, and recommend therein plans for improving the State system of forest protection, management and replacement.

SEC. 2. That the State forester shall, upon request, under the sanction of the board of directors, and whenever he deems it essential to the best interests of the people of the State, cooperate with counties, towns, corporations, or individuals in preparing plans for the protection, management, and replacement of trees, woodlots, and timber tracts, under an agreement that the parties obtaining such assistance pay at least the field expenses of the men employed in preparing said plans.

SEC. 3. That the governor of the State is authorized, upon the recommendation of the board of directors, to accept gifts of land to the State, same to be held, protected, and administered by said board as State forests, and to be used so as to demonstrate the practical utility of timber culture and water conservation, and as refuges for game. Such gifts must be absolute, except for the reservation of all mineral and mining rights over and under said lands, and a stipulation that they shall be administered as State forests.

The board of directors shall have the power to purchase lands in the name of the State, suitable chiefly for the production of timber, as State forests, using for such purposes any special appropriation or any surplus money not otherwise appropriated, which may be standing to the credit of the State forestry fund.

The attorney general of the State is directed to see that all deeds to the State of lands mentioned in this section are properly executed before the gift is accepted or payment of the purchase money is made.

SEC. 4. That all moneys received from the sale of wood, timber, minerals, or other products from the State forests, and penalties for trespassing thereon, shall be paid into the State treasury, and shall constitute a State forestry fund, and the moneys in said fund are hereby appropriated for purposes of forestry in general, under the direction of the board of directors.

SEC. 5. That for the maintenance, use, and extension of the work under the board of directors, and for forest-fire protection, there is hereby appropriated the sum of \$10,000 annually out of any moneys in the State treasury not otherwise appropriated, to be placed to the credit of the State forestry fund.

SEC. 6. That the board of directors may cooperate with the Federal Forest Service under such terms as may seem desirable.

SEC. 7. That all acts or parts of acts inconsistent with the provisions of this act are hereby repealed.

The above law as originally drafted also contained in section 3 the following:

Said State forests shall be subject to county taxes assessed on the same basis as are private lands, to be paid out of any moneys in the State treasury not otherwise appropriated.

But this paragraph was struck out by the legislature since it is unconstitutional for the State to pay taxes.

HOW THE FEDERAL GOVERNMENT WILL AID.

The Federal Government offers aid in forestry to States along three different lines: (1) Demonstration work at State experiment stations, (2) farm woodlot management under the Smith-Lever law, and (3) fire protection under the Weeks law.

State experiment stations prepared to handle the work can secure cooperative assistance in investigating the proper methods of forest management, nursery practice, tree planting, and the like.

In connection with farm woodlot improvement the Forest Service is planning to get in direct touch with the farmer through the extension work of the United States Department of Agriculture and the States. This work has recently received a tremendous impetus through the passage of the Smith-Lever law. Under its terms a Federal appropriation is made each year to further agricultural extension work in the States through the medium of the extension staff of the State agricultural college. To avail itself of the funds provided by this law a State must appropriate for this particular line of work an amount equal to that made available by the Federal Government. The law makes possible much cooperative work between the Federal Government and State agricultural colleges through inspection and practical field demonstrations by agents of the United States Department of Agriculture. Cooperative projects

can be proposed by the State, but must be approved by the Department. Since woodlot management is to a large extent a farm problem, the aim is to acquaint the county field agents of the State extension service with the essential principles of woodlot management in order that they may show the farmer how to manage his woodlands. Such projects have already been conducted in Tennessee and Indiana.

Of most immediate concern to a State which is just organizing its forest work is the Federal cooperation which can be secured in fire protection. Under the Weeks law the sum of \$100,000 was appropriated for the fiscal year 1916 for allotment to the States, to be expended in protecting the watersheds of navigable streams, provided the State establishes by law a system of fire protection and makes an appropriation therefor, and provided further, that the State expends at least as much as the Federal Government. This cooperation has been in effect for nearly five years, and the results secured in conserving our natural resources have far exceeded the anticipation of its most enthusiastic supporters. The States which are receiving funds under the law are: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Maryland, Virginia, West Virginia, North Carolina, Kentucky, Texas, Michigan, Wisconsin, Minnesota, South Dakota, Montana, Idaho, Oregon, and Washington, 21 in all. The remaining States in the southern pine region should not let the opportunity pass for securing cooperation of this character in keeping down their forest-fire losses.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO THE CONSERVATION OF FORESTS.

AVAILABLE FOR FREE DISTRIBUTION.

- Forest Planting in the Eastern United States. (Department Bulletin 153.)
The Northern Hardwood Forest: Its Composition, Growth, and Management. (Department Bulletin 285.)
Shortleaf Pine: Its Economic Importance and Forest Management. (Department Bulletin 308.)
Primer of Forestry. (Farmers' Bulletin 173.)
Primer of Forestry. Part 2—Practical Forestry. (Farmers' Bulletin 358.)
The Profession of Forestry. (Forestry Circular 207.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

- Forest Planting in Western Kansas. (Forestry Bulletin 52.) Price, 10 cents.
Working Plan for Forest Lands in Berkeley County, South Carolina. (Forestry Bulletin 56.) Price, 10 cents.
The Natural Replacement of White Pine on Old Fields in New England. (Forestry Bulletin 63.) Price, 10 cents.
Advice for Forest Planters in Oklahoma and Adjacent Regions. (Forestry Bulletin 65, revised.) Price, 5 cents.
Working Plan for Forest Lands in Central Alabama. (Forestry Bulletin 68.) Price, 10 cents.
The Forests of Alaska. (Forestry Bulletin 81.) Price, 25 cents.
Protection of Forests from Fire. (Forestry Bulletin 82.) Price, 15 cents.
The Crater National Forest: Its Resources and their Conservation. (Forestry Bulletin 100.) Price, 10 cents.
Forest Planting in Western Kansas. (Forestry Circular 161.) Price, 5 cents.
The Status of Forestry in the United States. (Forestry Circular 167.) Price, 5 cents.
Forest Planting in the Northeastern and Lake States. (Forestry Circular 195.) Price, 5 cents.
Assistance to Private Owners in the Practice of Forestry. (Forestry Circular 202.) Price, 5 cents.

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LARKSPUR POISONING OF LIVE STOCK.

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PART I.—INTRODUCTORY.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE.

There is somewhat extensive literature in regard to the larkspurs. In this summary and review only the more important and significant publications are noted, with especial reference to those that treat of the poisoning of domestic animals.

The larkspurs have been known from very ancient times as poisonous and medicinal plants. Under the names *σταφίς ἀγρία* of Dioscorides and Hippocrates, *ἀγροτέρα σταφίς* of Nicander, *Astaphis agria* or *Staphis* of Pliny, and *Herba pedicularia* of Scribonius Largus, was probably recognized the species *Delphinium staphisagria* L. Under the name *Consolida regalis* were probably included several species. The question of the identity of the species noted by the ancients is discussed in some detail by Huth, 1895, pages 325 and 326.¹

¹ Full titles of articles referred to in the text are given in the list of literature at the end of the paper.

Pliny speaks of the use of the powdered seeds to destroy parasitic insects on the head and other parts of the body, and this has been its principal use up to the present time, although it has been recommended as a remedy for various ills. As an insecticide the seeds of *Delphinium staphysagria* or "stavesacre" have been much used, but other species have served the same purpose. The leaves, stems, and roots have had little medicinal use, and very little has been published in regard to their poisonous properties besides the investigations on American species. Pliny states that the flowers when ground up serve as a remedy for snake bite. Dioscorides says that the herb paralyzes scorpions when put upon them. Watt, 1890, page 65, says that the root is applied to kill maggots in the wounds of goats. Froggatt, 1900, page 181, recommends larkspur as an insect barrier in gardens. He says that locusts readily eat the leaves and flowers and are killed by them.

Outside of America very little has been published in regard to the poisonous effect of larkspur on the higher animals. Delafond, 1843, page 173, makes the statement that *Delphinium consolida* L. is poisonous to sheep. His evidence does not seem to be extensive, and apparently is based upon the fact that he found sheep dead and, on examination, discovered that they had been eating *Delphinium consolida*. Gerlach, 1845, page 125, says that *Delphinium consolida* has been considered poisonous, but incorrectly, and states that he has fed sheep for several days with the plant and that they ate it readily but received no harm. Dammann, 1886, page 840, quotes Delafond, saying that sheep eat *Delphinium consolida* freely and that when they eat much are poisoned, and states the results of Gerlach. He also quotes Beier, 1845, who tells of horses poisoned by an extract of seeds of *Delphinium staphysagria* in beer. Watt, 1890, page 64, says that the dew from the leaves of *Delphinium brunonianum* Royle falling on grass is said to poison cattle and horses. He also says, 1890, page 69, that the leaves of *Delphinium vestitum* are poisonous to goats. Macgregor, 1908, page 502, gives details of the poisoning of a horse by *Delphinium*.

From this brief review of the subject it appears that there is little definite evidence that domestic animals in Europe and Asia have been poisoned by larkspurs. Most of the statements are of a general character, no specific instances being given, and they are not based upon personal experiences of the authors. Statements to the effect that animals are poisoned by dew falling from the plants, as in the case of *Delphinium brunonianum*, must be dismissed as purely imaginative. It would seem, therefore, that in Europe and Asia not only is there no loss of domestic animals by larkspur, but also that there are hardly any reliable records of individual cases of poisoning.

It is in North America that practically all the losses of domestic animals from this plant have occurred, and even here the published records are brief and of comparatively recent date. Complaints of losses came, by letter, to the United States Department of Agriculture many years ago, and newspaper reports of losses have not been uncommon. Philip Miller, in 1760, says of a larkspur, which must be *Delphinium exaltatum* Aiton: "This plant grows naturally in most parts of North America, where, when the cattle happen to feed upon the leaves, it occasions great disorders in them." There seems to have been no other published statement of the poisoning of cattle until the paper by Aven Nelson, 1896, page 79, who said that *Delphinium geyeri* Greene is "frequently greedily eaten by hungry cattle with fatal results, caused by bloating." Earlier, in 1889, Irish, page 25, reported the feeding of cattle upon larkspur with no results. Wilcox, in 1897, published his paper on the poisoning of sheep by larkspur, and this was republished in the Fifteenth Annual Report of the Bureau of Animal Industry, 1898. He says, pages 39 to 43, that from a band of 2,000 yearling lambs, about 50 died and between 500 and 600 showed signs of sickness. Autopsies were made upon the dead animals, and in the stomach contents were found the stems, leaves, and roots of *Delphinium menziesii* D. C.¹ An examination was made of the range over which the sheep had been passing and it was found that the larkspur grew in considerable abundance, and there was evidence that the sheep had been feeding almost exclusively where there was a large quantity of larkspur. Not only that, but it was clear that they had eaten freely of the plant. An examination showed that the plants broke off readily above the root and the inference was that the grazing had been largely of the upper part of the plant, very little of the root having been consumed. After a careful inspection of the other plants upon the range the conclusion was reached that there was no other plant which could be responsible for these cases. Wilcox sums up the results in the following words:

Thus the post-mortem condition of the sheep, the finding of larkspur in the stomachs of the dead sheep, and the evidence from the field work that the larkspur had been eaten by them seemed to indicate conclusively that the larkspur was the cause of the trouble.

He then gives in some detail the symptoms of larkspur poisoning in sheep, which correspond very closely with the observations of other authors upon larkspur poisoning. In order to make the work more conclusive, extracts of larkspur were made upon the range of Mr. Vestal, at Bigtimber, Mont. The chloroform extract of 25 grams of the dried plant was fed to a lamb, producing symptoms of

¹ This is probably incorrectly determined and should be *Delphinium bicolor*.

poisoning in 30 minutes and death in 2 hours. A second lamb was given, hypodermically, one dram of the chloroform extract, and a third lamb received in a similar manner one dram of benzol extract. Both of these animals showed symptoms of poisoning in 15 minutes, but later recovered after having received, hypodermically, doses of atropine with inhalations of ammonia.

Knowles, in 1897, in the "First Annual Report of the Board of Sheep Commissioners of Montana," speaks of the losses of both cattle and sheep and recommends as remedies ammonia, alcohol, atropine, digitalis, and nux vomica. He says that the most serious losses are among sheep. This article was issued apparently as a circular of the Montana State veterinarian's office in advance of the publication of the report of the sheep commissioners.

Chesnut, in his three publications of 1898, speaks of *Delphinium tricorné* Michx., *D. geyeri* Greene, *D. menziesii* D. C., *D. recurvatum* Greene, *D. scopulorum* Gray, and *D. trolliifolium* Gray as poisonous to stock. Macoun, 1898, states in the Report on the Poison Weed of the Rocky Mountain Foothills that he examined the stomach contents of cattle that had died in the neighborhood of Calgary, making also an investigation of the plants of the region where the animals had died, and came to the conclusion that without doubt the deaths were caused by eating *Delphinium scopulorum* Gray. Willing, 1899, states that a number of sheep are supposed to have died from larkspur poisoning in the Cypress Hills district. In Bulletin No. 2 of the Government of the Northwest Territories, 1900, larkspur is discussed and the experience of Prof. Macoun is referred to, with quotations from Wilcox, 1897.

Wilcox, 1899, discusses the tall larkspur as a poisonous plant for cattle in Montana. He describes the locations in which the plant grows, giving a general description of the plant itself, and states that the principal losses of cattle occur in the spring, after late snowstorms, when the larkspur is the only plant which appears above the snow. He does not think that any very large number of cattle are poisoned in any single year, but that the sum total of the loss is a rather serious matter, and recommends that the cattle be kept away from the larkspur areas, especially after spring snowstorms.

In 1901 was published Chesnut and Wilcox's Stock-Poisoning Plants of Montana. This bulletin discusses in considerable detail *Delphinium glaucum* Wats. and *D. bicolor* Nutt. as poisonous plants, and details are given of the experimental feeding of these plants to rabbits and sheep. A series of experiments was made, using extracts of tall larkspur, identified as *Delphinium glaucum*. These extracts were made in water and alcohol. In one of the experiments the expressed juice of the plant before flowering was fed directly into the stomach of a sheep. Symptoms of poisoning were noticed,

although the animal recovered rather quickly. After expressing the watery material from the plant the alcohol extract of the residue was fed to a sheep. Symptoms of the effect of the alcohol were noted, but by comparison with a check which received the same amount of alcohol, it was decided that some of the symptoms were characteristic of larkspur poisoning. Two other experiments were made in which it was believed by the authors that the antidote used, potassium permanganate, overcame the effect of the poison. The discussion of tall larkspur is summarized as follows, page 73:

The tall larkspur is a plant widely distributed in Montana, occurring, as a rule, in well-defined areas, especially on mountain ranges.

It has for several years been suspected of poisoning cattle, especially after snowstorms in spring and autumn.

Our observations show that the plant is sometimes eaten by cattle with fatal results. Extracts of the leaves of young plants, when fed to rabbits, produce alarming symptoms, and the same was true in one case when fed to sheep.

Experiments on cattle and one sheep indicated that permanganate of potash is an effective antidote when given in the first stages of poisoning.

Cattle should be kept away from patches of larkspur, especially during snowstorms.

The following summary is given of the discussion in regard to purple larkspur, page 80:

The purple larkspur is a plant which is widely distributed in Montana, especially on foothills and mountains, where its deep-blue flowers are conspicuous over wide areas in springtime. For a number of years it has been considered fatal to sheep and occasionally to other stock and this view has been confirmed by our investigations. Sheep are more often poisoned by purple larkspur than are other domestic animals. Our observations during the past few years have shown a striking variation in the appetite of sheep with reference to this point.

Our experiments indicate that both the leaves and roots of young plants are poisonous and that the plant is most dangerous during the early stages of growth before flowering.

The previous experience of one of us has shown that atropine is the best antidote for counteracting the physiological effect of this plant. Permanganate of potash and sulphate of aluminum should be administered as a chemical antidote.

Bessey, 1902, says that there have been serious losses in western Nebraska from *Delphinium nelsonii* Greene, and that the losses occur before the flowering of the plant. Slade, 1903, speaks briefly of Delphinium, the statements apparently being largely compiled from the work of Wilcox. Blankinship, 1903, describes briefly the tall and the low larkspurs. He says that larkspur frequently causes bloat, and gives other symptoms of poisoning, stating that cattle are mainly affected, sheep more rarely. He advises keeping stock away from ranges where low larkspur is abundant, especially during the early spring, and states that it is feasible to dig up the tall larkspur over limited areas.

S. B. Nelson, in 1906, performed a series of experiments, feeding *Delphinium menziesii* D. C. and *D. simplex* Dougl. Eight experiments were made with *Delphinium menziesii*, consisting of the direct feeding of both mature and immature plants, and of hypodermic injections of alcoholic and chloroform extracts. As much as 26 pounds of this plant, gathered in full bloom, was fed and apparently 3 pounds and 10 ounces of *Delphinium simplex*. All of these experiments were without results and he reached the definite conclusion that *Delphinium menziesii* is not poisonous to sheep and therefore that they may be allowed to graze where this plant grows in abundance without any fear of loss.

Glover, 1906, gives a somewhat extended description of the larkspurs as poisonous plants. He finds that five species of larkspur are abundant in Colorado—*Delphinium nelsonii* Greene, *D. elongatum* Rydb., *D. geyeri* Greene, *D. barbeyi* Huth, and *D. penardii* Huth. He made an attempt to get exact information from the stockmen of Colorado in regard to their losses and the remedies used, and summarized the results obtained from the circulars sent out. He describes in some detail the appearance of the larkspurs, the symptoms of poisoning, and discusses the best methods of treatment. He says:

From the reports in other Western States, especially Montana, it would seem that the purple larkspur which is more generally eaten by sheep is the more disastrous of the two. In this State it is quite the reverse. The tall larkspur is more abundant and the major part of the mortality is among cattle.

It would seem from this that Dr. Glover does not question the fact that sheep may be poisoned by eating larkspur. The same thing is indicated by his giving the symptoms of larkspur poisoning in sheep, page 23. He summarizes the conclusions obtained in regard to larkspur poisoning, as follows, page 18:

First. At least 18 species, and several varieties of larkspur, have been found growing in the State. Four growing in the greatest abundance are known to contain an active poison in sufficient quantities to be dangerous to live stock.

Second. Death is produced as a result of the presence of an active poison, and not from "bloat," as many stockmen have claimed.

Third. The toxic principle of larkspur has not yet been determined for these species, but is probably delphinin and allied alkaloids present in other species that have not been fully studied.

Fourth. The plant loses its toxic qualities as it approaches the flowering season and finally becomes harmless.

Fifth. Two species, because of their abundance, are doing most of the damage, i. e., tall larkspur (*Delphinium elongatum*) and purple larkspur (*Delphinium nelsonii*).

Sixth. Stockmen generally have little knowledge of the identity, poisonous nature, or satisfactory remedy for larkspur.

Seventh. Considering the enormous loss and the fact that larkspur is usually found in circumscribed areas, it would seem feasible, in many localities at least, to undertake its eradication by the grubbing hoe.

Eighth. By avoiding the areas where larkspur abounds during the months of April, May, and June the loss can be reduced to the minimum.

Ninth. In potassium permanganate and atropin sulphate, respectively, we have a chemical and physiological antidote of real practical value. Stimulants are indicated. Tapping should be done with trocar and cannula high up on the left side, after first making slight incision on the skin with a knife. In case of extreme distention this operation should not be delayed. The value of bleeding is questionable. All measures which tend to depress the animal, such as forcible exercise, tobacco, aconite, etc., are positively harmful. If on sloping ground, the head should be turned up the hill.

Crawford, 1907, quotes preceding authors in regard to the effect of larkspur upon stock, but adds nothing to what has been written before. Pammel, 1910, page 44, states that "cattle and sheep are most susceptible, although horses frequently suffer."

Preceding the publication of the present general report on the larkspur investigation, there was issued in 1913 Farmers' Bulletin 531, entitled "Larkspur or Poison Weed," which gave some of the practical results of the work. In 1915 Hall and Yates recapitulate the results of this bulletin, applying them to the larkspurs of California.

It will be seen from the foregoing that up to the time when the detailed experiments of larkspur poisoning were undertaken by the Bureau of Plant Industry, a very definite body of evidence had been accumulated indicating that American larkspurs were poisonous to domestic animals, especially cattle and sheep, causing heavy annual losses in the mountain ranges. There was a fair amount of agreement in the descriptions of the symptoms of poisoning. The remedial measures recommended were very largely those worked out by Wilcox, and by Chestnut and Wilcox in their Montana work. There were, however, several questions with regard to the poisoning which for practical purposes had to be decided. In the published observations and in the statements made by stockmen, the reports were somewhat contradictory with regard to which part of the plant is most poisonous, although there was a general agreement that the principal losses occur in the spring. It seemed necessary to determine at what time of the year and under what conditions these plants are poisonous, to determine whether the tall larkspurs and the low larkspurs are equally poisonous, to describe in somewhat greater detail the symptoms of poisoning and pathological results, and to make further and more detailed experiments upon the possibilities of using remedial measures to lessen the losses. There were also open questions concerning the best method of handling stock so as to prevent poisoning.

It may be noted that practically all accounts of larkspur poisoning of stock in the United States relate to the mountainous regions of the West. As will be seen later in this paper, there is no reason to

think that the eastern species are not poisonous, but conditions of grazing are so different in the East that cattle do not come in contact with the plant to any extent. Recently specific accounts have come to this office of the poisoning of cows by *Delphinium tricorne* in West Virginia.

For convenience of reference, there is given below a list of the species of *Delphinium* that are said to be poisonous to stock in the United States. This list is compiled from the literature of the subject, from office correspondence, and from personal interviews with stockmen, and no attempt has been made to edit it critically from the standpoint of the systematist. So far as specimens have come to the office of Poisonous Plant Investigations they have been determined by botanists of the Bureau of Plant Industry, but published statements have been taken at their face value.

Delphinium andersonii Gray.
Delphinium barbeyi Huth.
Delphinium bicolor Nutt.
Delphinium californicum T. & G.
Delphinium carolinianum Walt.
Delphinium consolida L.
Delphinium cucullatum A. Nels.
Delphinium elongatum Rydb.
Delphinium exaltatum Ait.
Delphinium geyeri Greene.
Delphinium glaucum Wats.
Delphinium hesperium Gray.
Delphinium macrophyllum Wooton.
Delphinium menziesii D. C., *D. nelsonii* Greene.

Delphinium multiflorum Rydb.
Delphinium occidentale Wats.
Delphinium recurvatum Greene.
Delphinium robustum Rydb.
Delphinium sapellonis Ckll.
Delphinium scaposum Greene.
Delphinium scopulorum Gray.
Delphinium simplex Doug.
Delphinium treleasei Bush.
Delphinium tricorne Michx.
Delphinium trolliifolium Gray.
Delphinium virescens Nutt., *D. penardii* Huth.

THE ALKALOIDS OF DELPHINIUMS.

Most of the laboratory work on the poisonous properties of the *Delphiniums* has been done in Europe on the seeds of *Delphinium staphisagria*, inasmuch as the seeds of this plant have been used since ancient times as a parasiticide and to some extent for medicinal purposes.

The analysis of the seeds of *Delphinium staphisagria* shows that they contain four alkaloids, namely, delphinin or delphin, delphinoidin, delphisin, and staphisagrin. The chemical composition of these alkaloids has been given somewhat differently by investigators. Marquis, 1877, who claimed to have first obtained the pure alkaloids, gives the formulas as follows:

Delphinin, $C_{22}H_{35}NO_6$.
 Delphinoidin, $C_{42}H_{68}N_2O_7$.

Delphisin, $C_{27}H_{46}N_2O_4$.
 Staphisagrin, $C_{22}H_{33}NO_6$.

The most characteristic and important alkaloids are delphinin and staphisagrin, and of the two, delphinin has been investigated the more thoroughly and is the more powerful alkaloid. The results

obtained by the various authors who have investigated the physiological action of delphinin have been somewhat contradictory, although the principal symptoms obtained in poisoned animals seem to be quite constant. The cause of some of the discrepancies is probably due to the fact that all the preparations of delphinin used in the various experiments have not been identical. A large variety of animals have been used in the physiological experimentation, including mammals, birds, reptiles, amphibians, and fish, although most of the experiments were performed on frogs and dogs.

Orfila in 1817 gives the following summary of conclusions:

First. That stavesacre is not absorbed, and that its deleterious properties depend on the local irritation it produces and the sympathetic lesion of the nervous system.

Second. That the part soluble in water is most active; so likewise the local effects of its administration are more severe when it is moistened before being applied to the cellular texture.

In 1843 he obtained the following symptoms with delphinin in dogs: For about two hours, nausea and attempts to vomit; then great agitation for some minutes, the dog soon becoming weak and finally lying motionless on its side; slight convulsive movements of the muscles of the legs and lower jaw, followed by death after two or three hours. The organs of sight and hearing remained normal until death. The autopsy showed the mucous membrane of the stomach to be slightly inflamed; the left ventricle contained dark-colored blood, and the lungs were more solid than normal.

Falck and Röhrig in 1851 obtained in cats and dogs vomiting, excessive salivation, diarrhea, uneasiness, staggering gait, convulsions, difficult breathing, followed by death from asphyxiation and heart paralysis. The autopsies showed congestion of the mucous membranes which had come in contact with the poison, the heart and great veins gorged with blood, and the lungs covered with ecchymotic spots. Later authors do not vary much in regard to the general symptoms. Van Praag and Turnbull note in addition a diuretic effect.

Cayrade, 1869, states his conclusions as follows:

1. The delphinin acts upon the spinal cord, causing depression and making it lose its excito-motor power.
2. The effects are gradual and are felt from below upward, the reflex power being lost progressively, first in the lower limbs, then in the upper limbs, and, finally, in the head.
3. The voluntary movements continue after the loss of the reflex movements and become incoordinate before their disappearance.
4. The facts observed in the study of normal reflex movements and during the poisoning of the cord by delphinin justify the belief that the nerve cells of the gray matter may lose their power of direct reaction and yet permit the passage of the reflex current.

5. The delphinin seems to act successively and with a paralyzing effect upon the general sensitiveness, the reflex power, the respiration, and the coordination of movements. Its favorite place of predilection is the nervous system and it has no influence on the muscular system.

According to most authors convulsions come on in the later stages of the poisoning, with intervals in which the animal is in a comatose condition. Characteristic of Delphinium poisoning are the muscular tremblings which start in the abdominal muscles and pass over the body. Although most of the authors agree in general on the symptoms and the anatomical lesions exhibited by animals poisoned by delphinin, there is some disagreement as to the way the poison acts in bringing about the observed results. Several authors have compared delphinin to veratrin, and some have compared it to curare, while most of them find that its action is similar to that of its near relative aconitin. It certainly is true that the action of delphinin on experimental animals, as given by most authors, corresponds very closely with the recognized action of aconitin. The principal difference seems to be that delphinin has a direct depressing action on the vasomotor centers of the cord (Boehm and Serck) and that it does not paralyze the heart muscles to any extent (Schiller). Some of the earlier authors attributed the paralysis of Delphinium poisoning to a paralyzing action on the muscles similar to that caused by veratrin, but it has been established that delphinin exerts its essential action on the nervous system rather than directly on the muscles.

Rabuteau and some others advance the theory that the paralysis is due, as in the case of curare poisoning, to the paralysis of the motor end organs rather than to a depression of the nerve centers; while Boehm and Serck describe experiments which show that the preparation of delphinin used by them acted on the motor nerve centers rather than on the end organs.

The chlorid of the alkaloids in the American Delphiniums has been separated by Lohmann and put upon the market by Merck under the name of Delphocurarine, with the idea that it may be used as a drug instead of curare. This has been discussed in some detail by Heyl, 1903.

Authors seem to agree that the slowing of the respiratory movements and the final asphyxiation are due to depression of the respiratory centers in the medulla oblongata and the afferent vagus fibers. Boehm and Serck, 1876, show that death is delayed by using artificial respiration, indicating that asphyxiation is the immediate cause of death rather than the stopping of the heart. They also found that immediately after injections of delphinin, both pulse rate and blood pressure fell, due to the stimulation of the vagus. This is followed by a rise due to paralysis of the vagus through continued action of the poison. If the dose is repeated or if the original

dose is large, the pulse rate and pressure rapidly fall again and the heart stops in diastole.

Hahn, in concluding his article in 1882, gives the following résumé:

The delphin, after having caused a local irritation, which is not very intense in the first stages, manifests its action on the respiration (slowing of the respiratory movements, death by asphyxiation), on the organs of circulation (slowing of the beatings of the heart, lowering of the blood pressure, stopping of the heart in diastole), on the spinal cord (loss of the excito-motor power of the spinal cord, rapidly progressive general anesthesia, convulsions, and paralysis); moreover, the muscles are the seat of intense fibrillar shocks. In its toxic effects delphin then very much resembles the alkaloids of aconite, as one would expect from the botanical relationships; it is distinguished by its energetic action on the nerves supplying the muscles, an action which aconitin does not possess except in a feeble degree.

Keller and Völker in 1913 report the separation from *D. ajacis* of two alkaloids, ajacin and ajaconin. The formula for ajacin is given as $C_{15}H_{21}NO_4H_2O$ and of ajaconin as $C_{17}H_{29}NO_2$. The properties of these alkaloids are given, but apparently no experiments were made to test their effect upon animals.

In 1913 Loy, Heyl, and Hepner made a report of analytical work on Wyoming larkspurs. They isolated an alkaloid in an impure form and made quantitative determinations in *D. nelsonii*, *D. glaucum*, and *D. geyeri*. They state that of these three species, apparently *D. geyeri* is the most poisonous. They find in *D. nelsonii* that the seed contains of the crude alkaloid 1.27, the flower 0.79, the pod 0.60, the root 0.48, the leaf 0.34. In *D. glaucum* they find in the root 1.79, in the flower 0.77 and in the leaf 0.62. In *D. geyeri*, they find in the leaf and stem 1.15 and in the root 0.93.

As is noted later, page 77, the apparent greater toxicity of *D. geyeri* may possibly be explained by the age of the plant.

A review of the laboratory work on the poisonous principles of the Delphiniums brings us to the general conclusion that we have in these plants a poisonous principle similar in its action to that of aconitin. The poison is a local irritant causing strong convulsions in the animals as well as pain and nausea. Its systemic action is on the nervous system, depressing the respiratory and vasomotor centers, and paralyzing the motor centers in the cord. The immediate cause of death, then, is asphyxiation; the heart action also is weak and stops about as soon as respiration ceases.

In the summing up of the work of the field experimentation on the Delphiniums, it will be noted that these symptoms agree quite fully with those noted in animals poisoned by feeding upon the plants at the Mount Carbon station.

LOSSES FROM LARKSPUR POISONING.

It is very difficult to get anything like exact statistical reports of the losses caused by larkspur poisoning. In many localities all cases

of poisoning are attributed to this plant, although the stockmen may have a very indefinite idea of what larkspur really is. In other cases, where they have learned that some other poisonous plant has been responsible for the death of animals, larkspur losses, without any doubt, are overlooked. Generally speaking, however, so far as the reported larkspur poisoning refers to the summer ranges in the mountains, considerable reliance can be put upon the facts presented. This is generally true where the losses refer to cattle rather than to sheep.

The reports of Wilcox, 1897, and Chesnut and Wilcox, 1901, give some details with regard to losses of sheep in Montana, Wilcox stating that out of one band of 2,000 yearling lambs, 102 died. The authors, also, have been told by Mr. L. W. Bailey, of Casper, Wyo., that in the Big Horn region in 1908, 7,000 sheep were lost. Mr. Jeff. Crawford, of Casper, stated that in 1907, in the months of April, May, and June, he lost 23 per cent of his sheep. Both Mr. Bailey and Mr. Crawford supposed that the sheep died from larkspur poisoning. As is indicated elsewhere in this report, however, the authors very much doubt whether larkspur is ever the cause of fatalities in the case of sheep, so that in discussing larkspur losses it is felt that the sheep losses can be ignored.

More complete reports of losses have been made from the State of Colorado than from any other region, largely, without doubt, because the experiment work of the Department of Agriculture upon the larkspurs has been mainly centered in that State. Glover, 1906, estimated that the annual losses among the Colorado cattle herds amounts to \$40,000. A few concrete examples collected by the authors will give a more definite idea of what this loss means in individual cases:

Mr. Hartman, of Crystal Creek, Colo., reports that in 1884 or 1885, on the Curecanti, out of 500 head of cattle, 35 died within 5 hours. Mr. Creighton, of Crystal Creek, stated that out of one herd of 3,000, 200 died; and out of another of 5,000, 200 died, while from a herd of 6,000, 196 died. The latter fact was not an estimate, but was carefully tallied by one of the stockmen. In 1908, in Washington Gulch, Gunnison County, Colo., 12 head of cattle were found dead. In the same year in a gulch at the upper part of Red Creek in the same county, 22 head of cattle died between 2 o'clock Saturday, June 27, and 2 o'clock Sunday, June 28. In this case nearly all of the cattle belonged to one man. In District No. 4 of the Uncompahgre National Forest, in the spring of 1909, according to the report of Supervisor Spencer, 100 cattle died. Near Axial, Colo., in 1908, Mr. Iles lost 200 head of cattle. In the same year in an area of six or seven square miles near Axial, 25 head of cattle died out of a total of 800. One man in Del Norte, Colo., was reported by the

forest supervisor as having lost 15 per cent of all his cattle. On the Fishlake National Forest in 1915, it was estimated by the forest supervisor that there was a total loss of cattle amounting to \$15,000, one man losing 48 out of a total of 400 head.

An attempt has been made from reports that have been sent in from the various grazing areas to get an idea of the percentage of cattle losses. These percentages can not be considered as very reliable, the estimates made varying from 3 to 7 per cent. A considerable number of the persons reporting make an estimate of 5 per cent. This is a very heavy toll to take of the stockmen, and it is probable that with the exception of the losses from loco poisoning, there is no one cause of loss that draws upon the herds so heavily as larkspur poisoning.

The specific examples which have been given have been largely from Colorado, but losses occur in most of the summer ranges in the mountain regions of the West, and it is probable that the apparently greater losses from Colorado are due in part to the more complete reports and in part, perhaps, to the fact that in Colorado there is a larger extent of valuable summer range than in the other States. The reports of losses in the United States come from all the mountain regions between Mexico and the Canadian line and from the Rocky Mountains on the east to the coast ranges on the west. Similar losses have been reported from the Canadian ranges. The major part of these losses occur in May, June, and early July.

COMMON NAMES OF LARKSPURS.

In Europe a number of common names have been applied to the larkspurs, names derived either from the morphology of the plant or its assumed characteristics. Perhaps the most common name is "stavesacre," a corruption of *Staphysagria*. In England they are also known as "dolphin flower," "king's consound," "knight's spur," "staggerweed," and "lousewort." In Germany the common names are "Rittersporn," "Lerchen Klaue," and "Horn Kummel." In France, "pieds d'alouette," "herbe Sainte-Athalie," "fleur d'amour," are among the more common names.

In the western United States larkspurs are commonly known as "poison," "poison weed," and "cow poison," while in parts of New Mexico the term "peco" is used. In the mountain ranges of the West the larkspurs are generally known and accurately distinguished by the men who handle stock. Before the plants blossom, however, some confuse *Delphinium* and *Geranium*, and more fail to distinguish between *Delphinium* and *Aconitum*. The leaves of the aconites resemble the larkspur so closely that, inasmuch as they grow in the same localities, it is not strange that they are not always

recognized as different plants. The flowers of larkspur and aconite are so different, however, that few fail to recognize the difference after flowering.

SPECIES OF DELPHINIUM CONCERNED IN LARKSPUR POISONING.

The classification of the species of *Delphinium* is in a somewhat unsatisfactory condition, and until a thorough revision of this genus has been made it is hardly possible to speak authoritatively in regard to the distribution of the various species. Generally speaking, we find two great groups, the tall and the low larkspurs. The tall larkspurs embrace the species that are more or less closely related to the old species *Delphinium scopulorum* Gray. The form that has been used in the experimental work in Colorado is known provisionally as *Delphinium barbeyi* Huth, and grows at an elevation of 8,000 feet and higher. *Delphinium robustum* Rydb., with which a single feeding experiment was carried on, is also a tall larkspur. The tall larkspur used in the feeding experiment at the Greycliff station was *Delphinium cucullatum* A. Nels., which is common in the mountains of Montana. The species of low larkspur used at the Mount Carbon station was *Delphinium menziesii* D. C., of which the name *Delphinium nelsonii* Greene, is a synonym, while that fed in Montana was *Delphinium bicolor* Nutt. The tall larkspurs grow throughout the season, maturing in the late summer while the low larkspurs mature and die early in July. Although experimental work has not been carried on by the authors in any other States than Colorado and Montana, there is every reason to think that the plants found in other localities have the same properties and produce the same effects as the larkspurs of Colorado.

From the fact that the low larkspur dies early in July, cases of poisoning from this plant occur mainly in the month of June, and it is commonly thought by the stockmen that the plant ceases to be poisonous when it blossoms; but as shown elsewhere in this report, it is probable that it is poisonous during its whole life. The fact that fewer cases of poisoning occur when the plant is in flower is probably because at that time nutrient grasses are more abundant and the animals eat less of the larkspur. The tall larkspurs are also poisonous early in the season and these poisonous properties, as shown elsewhere, may continue until the maturity of the plant. The cases of poisoning which occur in other States are due to species which correspond in general with the tall and low larkspurs of Colorado.

DELPHINIUM BARBEYI Huth.

Delphinium barbeyi (Pl. I) is a perennial, growing from buds at the apex of a long woody root. The stems are pubescent and more

or less viscid. The leaves are large and deeply cleft into about five segments, and these segments are more or less deeply incised. The leaf segments are oblong or obovate-cuneate. The blue-violet flowers are in a dense terminal raceme, the pedicels being longer than the spurs. The ovaries are bluish.

Delphinium barbeyi has a lower limit of altitude of about 8,000 feet, growing from that point nearly to the timber line. It grows best in damp valleys and canyons, where it may form dense masses. It is found in the mountains of Colorado, Wyoming, and Utah, and perhaps in the adjoining States to the north and south. It starts growth early in the spring and at the Mount Carbon station attains a height of from 1 to 2 feet by the month of June, forming succulent bunches much more prominent than the grass, and doubtless somewhat attractive to grazing animals. The plant grows to a height of from 3 to 7 feet, the blossoms appearing about the 1st of July and the seeds the latter part of the month. The exact time of flowering varies, of course, with the season and the altitude. All vegetation at the Mount Carbon station was from one to two weeks earlier in 1910 than in 1909, and at Kebler Pass, 1,000 feet higher than the station, flowering plants were collected for feeding as late as the middle of August. The seeds are shed very soon after being matured, and the plant begins to dry up, the stems and leaves gradually becoming brown and dry.

DELPHINIUM CUCULLATUM A. Nels.

Delphinium cucullatum (Pl. II, fig. 1) resembles *Delphinium barbeyi* very closely in its habit and occurrence. The stems are glabrous and the leaves divided into three to seven segments. The terminal racemes are closely flowered. The sepals are bluish-white, the petals violet, and the ovaries white. The general appearance of the flowers is bluish-gray, this coloration appearing to be constant for the species. Near the Greycliff station the plants blossomed the last of July.

D. cucullatum is found in Montana, Wyoming, Idaho, and as far south as central Utah.

DELPHINIUM ROBUSTUM Rydb.

Delphinium robustum is a perennial occurring in the mountains from Montana to New Mexico and grows in the same general way as *Delphinium barbeyi*. The stems are puberulent but not viscid. The leaves are divided into five to seven segments, which are long and twice cleft into linear lobes. It has the same general habits as *Delphinium barbeyi*, but does not confine itself so closely to the canyons and is readily distinguished from *barbeyi* by the form of the leaves.

DELPHINIUM MENZIESII D. C.

Delphinium menziesii (Pl. II, fig. 2, and Pls. III and XIII) is a perennial, growing from a cluster of small tuberous roots from which the stem is easily detached. The stem is slender, simple, and puberulent. The leaves are deeply cleft into segments which are linear in form. The flowers are deep violet-blue in color, on slender pedicels, and arranged in a loose raceme. There may be as few as four to six flowers, but they are more numerous on thrifty plants growing in favorable locations.

Delphinium menziesii grows at altitudes of from 4,000 to 12,000 feet. It is found on open hillsides and in parks, growing in great abundance. The picture of Pass Creek Park (Pl. III) gives an idea of the number of plants found in that locality. When they were in blossom the surface of Pass Creek Park as seen from a neighboring hill presented a uniform blue appearance. In June, 1908, Supervisor Kreutzer, of the Gunnison National Forest, with the senior author, picked and counted 1,340 of the plants in blossom on a square rod near Crystal Creek, Gunnison County.

Delphinium menziesii is widely distributed, being found from the Rocky Mountains to California and Oregon, and from Alberta to New Mexico. It appears soon after the snow has melted, and at high altitudes the plants may be found growing in immediate proximity to snow banks. It grows to a foot in height and the blossoms appear about the middle of May, the time of blossoming varying with the advancement of the season and the altitude. The seeds, which are formed the last of June, are immediately shed and the plant dies down and disappears. After the first week in July the plant is very rare except at the highest altitudes at which it grows.

DELPHINIUM BICOLOR Nutt.

Delphinium bicolor is a perennial growing from long fibrous fascicled roots. The stem is glabrous or pubescent, and the leaves deeply cut into linear lobes. The rather stout stem is short, not exceeding 12 or 15 inches in height. The raceme has a few flowers much larger than those of *Delphinium menziesii* and of a deep violet-blue color. It is one of the most beautiful of the American larkspurs.

It grows at a lower altitude than *Delphinium menziesii* and, so far as observed, never in such dense masses. Its range is given as from Washington and Oregon to South Dakota. It is the common low larkspur in Montana, and like *D. menziesii*, blossoms about the middle of May and disappears early in July.

DETECTION OF LARKSPUR SPECIES IN STOMACH CONTENTS.

In connection with these studies cases of poisoning not infrequently occur in which the cause of death can not be determined

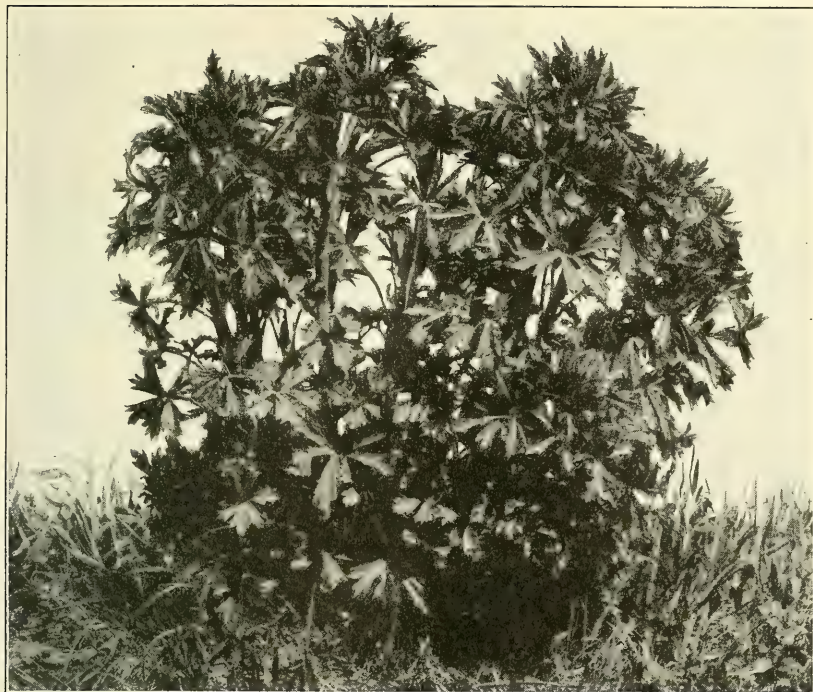


FIG. 1.—TALL LARKSPUR (*DELPHINIUM BARBEYI* HUTH) BEFORE FLOWERING.



FIG. 2.—TALL LARKSPUR (*DELPHINIUM BARBEYI* HUTH) IN FULL BLOOM.



FIG. 2.—LOW LARKSPUR (*DELPHINIUM MENZIESII* D. C.).



FIG. 1.—TALL LARKSPUR (*DELPHINIUM CUCULLATUM* A. NELS.).



PASS CREEK PARK, COLO., WITH LOW LARKSPUR (*DELPHINIUM MENZIESII*) IN BLOSSOM

from the readily available evidence, and recourse must be had to a study of the contents of the rumen. On account of the maceration of the plants most of the material is unrecognizable on macroscopic examination, the leaves especially being almost disintegrated. Frequently, however, stems of grasses and other plants retain their structure sufficiently to show some characteristic features, the fibro-vascular bundles in many cases being more or less intact when the looser tissues have been disintegrated.

As the poisoning due to *Delphinium barbeyi* was being investigated, an attempt was made to determine whether the stomachs of the poisoned animals contained this plant, by comparing sections of stems found in the rumen with sections of stems of *Delphinium barbeyi*. In this way it was found possible to determine whether an animal had eaten larkspur, and this method was successfully applied in a number of cases where portions of stomach contents had been preserved in formalin. This work led to the sectioning of stems of other species of *Delphinium* in order to discover whether it was possible to differentiate between the species by stem sections, especially since in the region where the station was located two species of larkspur occur. This work is here recorded, not in any sense as a complete study of the stem anatomy of the genus, but as a few interesting facts brought out by a comparison of cross sections of stems of a number of species of *Delphinium*.

In looking up the literature of this genus, no anatomical work was found on the American species. A number of articles have been published both in Europe and America on the anatomy of the Ranunculaceæ as a whole and of some of the other genera, but those dealing with *Delphinium* in detail are few and are European. In 1885 Albert Meyer published an article on the systematic anatomy of the Ranunculaceæ, in which he grouped the genera according to anatomical characters, and also differentiated many of the species, giving a key based on anatomical characters. His work was on the characters shown by cross-sections of stems. Paul Marié, 1885, published an extensive paper on the histological structure of the Ranunculaceæ. In this work the detailed anatomy of all parts of the plant is described for a number of species in each genus, and the distinguishing characters of the family and of the different genera are discussed. The only article which is devoted solely to the anatomy of *Delphinium* is that of Lenfant, 1897, on the genus *Delphinium* in a series of contributions to the anatomy of the Ranunculaceæ. The histological structure of four species (two of which, *ajacis* and *consolida*, have been introduced into the United States) is studied for all parts of the plant and for various stages of growth.

The present work includes the following 29 species of Delphinium: *D. ajacis* L., *D. andersonii* Gray (National Herbarium No. 419245), *D. barbeyi* Huth, *D. bicolor* Nutt., *D. blockmannæ* Greene (National Herbarium No. 2060), *D. californicum* T. & G. (National Herbarium No. 419726), *D. cardinale* Hook (National Herbarium No. 1928), *D. carolinianum* Walt. (National Herbarium No. 442717), *D. consolida*, L., *D. cucullatum* Aven Nelson, *D. decorum* F. & M. (National Herbarium No. 1939), *D. depauperatum* Nutt. (National Herbarium No. 529204), *D. geraniifolium* Rydb. (National Herbarium No. 245524), *D. geyeri* Greene, *D. glaucum* Wats., *D. menziesii* D. C. (National Herbarium No. 333235), *D. nudicaule* T. & G. (National Herbarium No. 612398), *D. occidentale* Wats. (National Herbarium No. 506615), *D. recurvatum* Greene, *D. robustum* Rydb., *D. sapellonis* Ckll., *D. scaposum* Greene, *D. scopulorum* Gray (National Herbarium No. 234530), *D. simplex* Dougl. (National Herbarium No. 226416), *D. tricornis* Michx., *D. trolliifolium* Gray, *D. variegatum* Gray (National Herbarium No. 342458), *D. variegatum apiculatum* Greene (National Herbarium No. 1887), and *D. virescens* Nutt.

These species were used, partly because they are the species which have been met in the field work on poisonous plants, and partly because they were convenient to obtain for comparison. The specimens of *barbeyi* and *menziesii* were from fresh specimens which were fixed and embedded in the field, from specimens preserved in alcohol, and from dried specimens. The sections of *sapellonis* and *cucullatum* were from dried plants sent in from the field. The remaining specimens were from the United States National Herbarium, the Economic Herbarium of the Bureau of Plant Industry, and from the collection of Mr. Ivar Tidestrom. In addition to these species of Delphinium, stem sections were made of two species of Aconitum, for the purpose of comparison, since the two genera are very similar in structure, and since the two occur side by side in the field and both are suspected of poisoning stock.

In preparing the dried herbarium material for sectioning it was treated with 2 per cent sodium hydroxid solution for 24 hours, or until the tissues were softened and swollen, then washed thoroughly in water, and put in a 10 per cent glycerin solution, the glycerin being gradually concentrated through a period of several days. The sections were then cut in pith with a hand microtome, and stained with safranin. Perfect sections are not always obtained by using this method, but for the purpose of the identification of stems in field work it is preferable in most cases to embedding.

Comparison of the different species was based solely on the characters appearing in the cross sections of stems. For each species

cross sections of the main stem of the plant were made without reference to any particular point in the stem. In the case of *Delphinium barbeyi* and *D. menziesii* and *Aconitum bakeri*, sections were made from the subterranean portion of the stem, the petiole, and the peduncle. A photomicrograph was made of a portion of a section of a stem of each species, all the photographs being magnified 65 diameters.

The sections of course showed certain characteristics typical of the Ranunculaceæ, the most noticeable being the form and disposition of the fibrovascular bundles. The bundles are of the closed collateral type and are isolated, being separated by wide mēdullary rays. The xylem mass has in cross section a somewhat V-shaped appearance, the arms of the V partially inclosing the cambium and phloem. There is no interfascicular cambium. This type of bundle is common to the Ranunculaceæ, but is found almost nowhere else among the dicotyledons (Solereider, 1908, p. 18, and Jeliffe, 1899, p. 339). Another feature of the bundle peculiar to the Ranunculaceæ among dicotyledons is that the phloem consists only of sieve tubes and companion cells, with no phloem parenchyma (Strasburger, 1908, p. 113). These facts in regard to the fibrovascular bundles serve to differentiate the Ranunculaceæ from other dicotyledons, but are also points of resemblance to some of the monocotyledons. Therefore in identifying larkspurs in the stomach contents of poisoned cattle it was necessary to differentiate carefully from some of the grasses when only fragments of the stem could be obtained.

The genus *Delphinium* has a characteristic stem structure, as shown by cross sections. Vesque, 1881, page 28, says that it is impossible to distinguish anatomically the genera of the Ranunculaceæ, but that certain groups of genera can be recognized, and he places *Aconitum* and *Delphinium* in one group. Myer, 1885, page 46, in his key, gives means of distinguishing both *Delphinium* and *Aconitum*, the latter being differentiated from *Delphinium* by the presence of a complete ring of sclerenchyma outside the fibrovascular bundles.

In cross section the external circumference of a *Delphinium* stem is either approximately circular or approaching an octagonal shape, and the stem is hollow. It is covered externally by a layer of epidermal cells whose outside walls form a thickened cuticle. The epidermis usually bears unicellular hairs of varying shape, size, and number, and is pierced by simple stomata. Beneath the epidermis there is a layer of hypodermal cells similar to those of the epidermis but without thickened walls. Inside the hypodermis there are two to five rows of cortical parenchyma cells, bearing chlorophyll, and arranged loosely with intercellular spaces. In one species it was possible to distinguish an endodermis, but as a rule the endodermis can not be distinguished from the other cells of the pericycle. The

pericycle consists of a ring of sclerenchymatous tissue between the cortex and the phloem portion of the fibrovascular bundles, and is composed of the bast fibers of the bundles and the interfascicular sclerenchyma. The cells of the pericycle have thickened walls, especially in the case of the bast fibers, the cells of which are also smaller than those of the interfascicular sclerenchyma. Inside the pericycle are the phloem and xylem portions of the fibrovascular bundles, the bundles being separated by the medullary rays, which are as wide as the bundles, and the cell-walls of which are sometimes thickened so that they are not distinctly marked off from the pericycle. The medullary rays are continuous with the medullary portion of the stem, in which there is a medullary lacuna of varying size.

The fibrovascular bundles are of the closed collateral type, arranged in a single circle, just inside the cortex. In this description the bast fibers are considered as part of the fibrovascular bundle. The group of bast fibers seen in cross section varies from a wedge shape to a somewhat circular shape, and is usually not sharply defined from the interfascicular portion of the pericycle. It partially incloses the phloem and cambium, while the curved outer border of the xylem partially incloses the cambium on the inner side. The phloem consists of sieve tubes and small companion cells. The cambium is composed of several rows of small thin-walled cells, elongated tangentially, lying in a curved line, with the convexity toward the xylem. Between and surrounding the tubes of the xylem proper is a varying amount of xylem parenchyma.

Classified according to cross sections of stems, the 29 species of *Delphinium* examined fall into six groups, as follows:

Group 1. *Delphinium barbeyi*, *D. californicum*, *D. cucullatum*, *D. geranii-folium*, *D. glaucum*, *D. occidentale*, *D. robustum*, *D. sapellonis*, *D. scopulorum*, *D. troliifolium*.

Group 2. *Delphinium andersonii*, *D. bicolor*, *D. decorum*, *D. depauperatum*, *D. menziesii*, *D. nudicaule*, *D. tricornae*.

Group 3. *Delphinium blochmannæ*, *D. cardinale*.

Group 4. *Delphinium carolinianum*, *D. recurvatum*, *D. simplex*, *D. variegatum*, *D. variegatum apiculatum*.

Group 5. *Delphinium geyeri*, *D. scaposum*, *D. virescens*.

Group 6. *Delphinium ajacis*, *D. consolida*.

These six groups may be combined in three main sections. Section I includes only group 1, which comprises all the species which are commonly known as tall or giant larkspurs. Section II includes groups 2, 3, 4, and 5, and in general represents those species known as low larkspurs. Section III consists of group 6, the European *consolida* group.

Delphinium barbeyi has been taken as the type of group 1. Figure 1, A, is a diagram of a cross section of a stem *D. barbeyi*,

with only part of the bundles drawn in; B is a diagram of a typical fibrovascular bundle of group 1. In *Delphinium barbeyi* (Pl. IV,

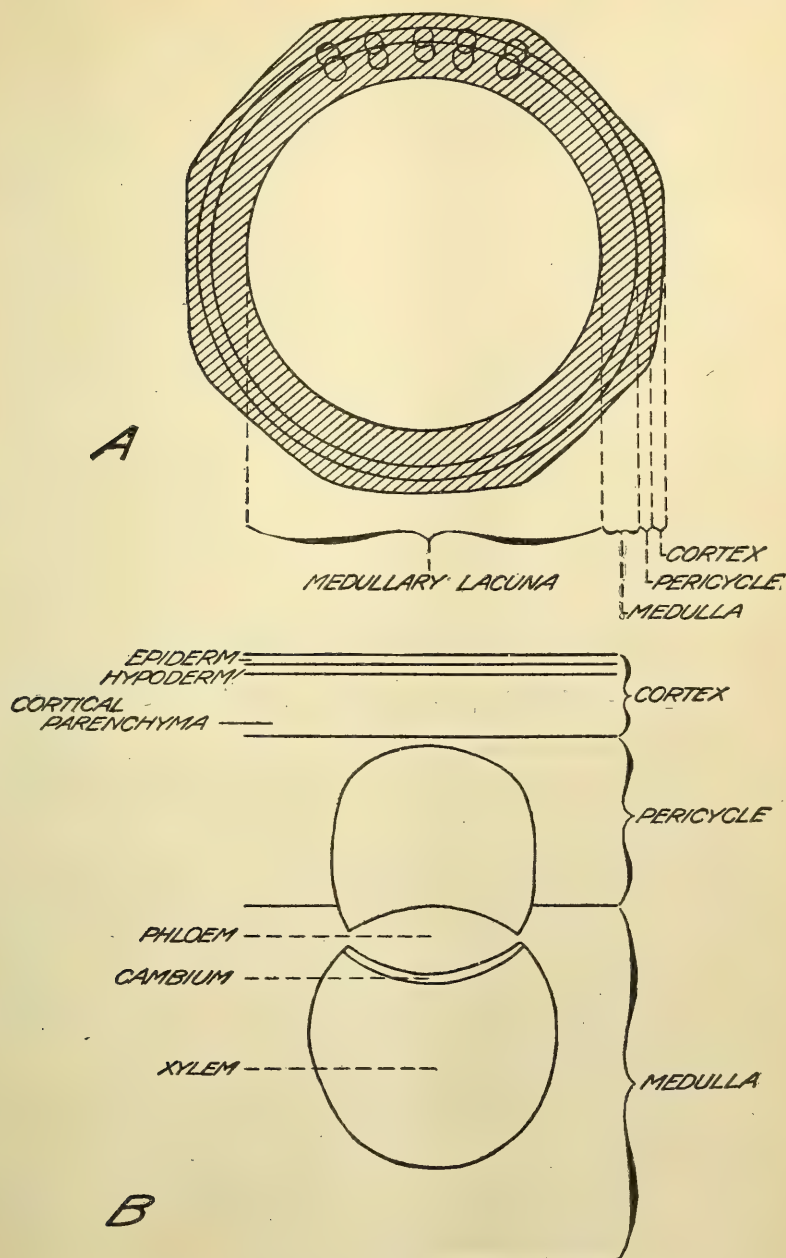


FIG. 1.—A: Diagram of cross-section of stem of group 1. B. Diagram of fibrovascular bundle of group 1.

fig. 1) the stem is large, with a large medullary lacuna. The outer circumference is roughly octagonal. The bundles are about 32 in

number, and rather small in proportion to the diameter of the stem, those at the angles being a little larger than the others. The cross sections of the xylem and the bast are about the same in size, both being somewhat circular in form. The horns of the bast mass and the xylem mass nearly inclose the lens-shaped phloem. There are only a few rows of xylem parenchyma at the inner end of the xylem. The walls of the cells of the pericycle are not very greatly thickened. The bast fibers of the bundles lying between the angles of the octagon are separated from the cortex by one or two rows of cells continuous with the interfascicular sclerenchyma.

As a type of the second group, *Delphinium menziesii* has been used (Pl. IV, fig. 2). The stem is much smaller than that of *Delphinium barbeyi* and has a medullary lacuna much smaller in proportion to the diameter of the stem. The circumference of the stem is practically circular. The bundles are about 24 in number, of two sizes arranged alternately. The fibrovascular bundle exhibits in cross section a form quite distinct from that of group 1. The bundle is longer and narrower, the bast being wedge-shaped with the larger end situated externally. The phloem portion of the bundle is open laterally, the inner boundary of the bast and the outer line of the xylem being only slightly curved. The xylem proper is small in extent, but there is a large amount of xylem parenchyma extending toward the medullary lacuna.

Group 3 is represented by *Delphinium cardinale* (Pl. V, fig. 1), and in type of stem structure can not be differentiated from group 2: The group 2 type is here exhibited on a larger scale, with a bast larger in amount, and more sharply differentiated from the interfascicular sclerenchyma, and composed of thicker-walled cells, and with a stouter structure all the way through.

In group 4, typified by *Delphinium recurvatum* (Pl. VI, fig. 1), we have a stem structure which may be considered as intermediate between the true low larkspur type of group 2, and the taller forms represented in group 5. The general form of fibrovascular bundle corresponds to that of group 2, but the stem is more compact in structure, the bundles longer and arranged more closely, and the alternate large and small bundle arrangement less prominent.

For the fifth group, *Delphinium geyeri* was used as the type (Pl. V, fig. 2, and fig. 3, A and B). The medullary lacuna of the stem is very small and the external circumference approaches the octagonal. The bundles are about 30 in number, those at the angles being slightly larger than the others. The cells of all the tissues of the stem are relatively small and numerous. The fibrovascular bundle is similar in the form of cross section to that of group 2, but is larger and much elongated, the bast in particular being very extensive. The bast is oblong to wedge-shaped, and composed of very

small, heavy-walled cells. The xylem proper is small in amount, generally curved at the outer boundary more than is the case in

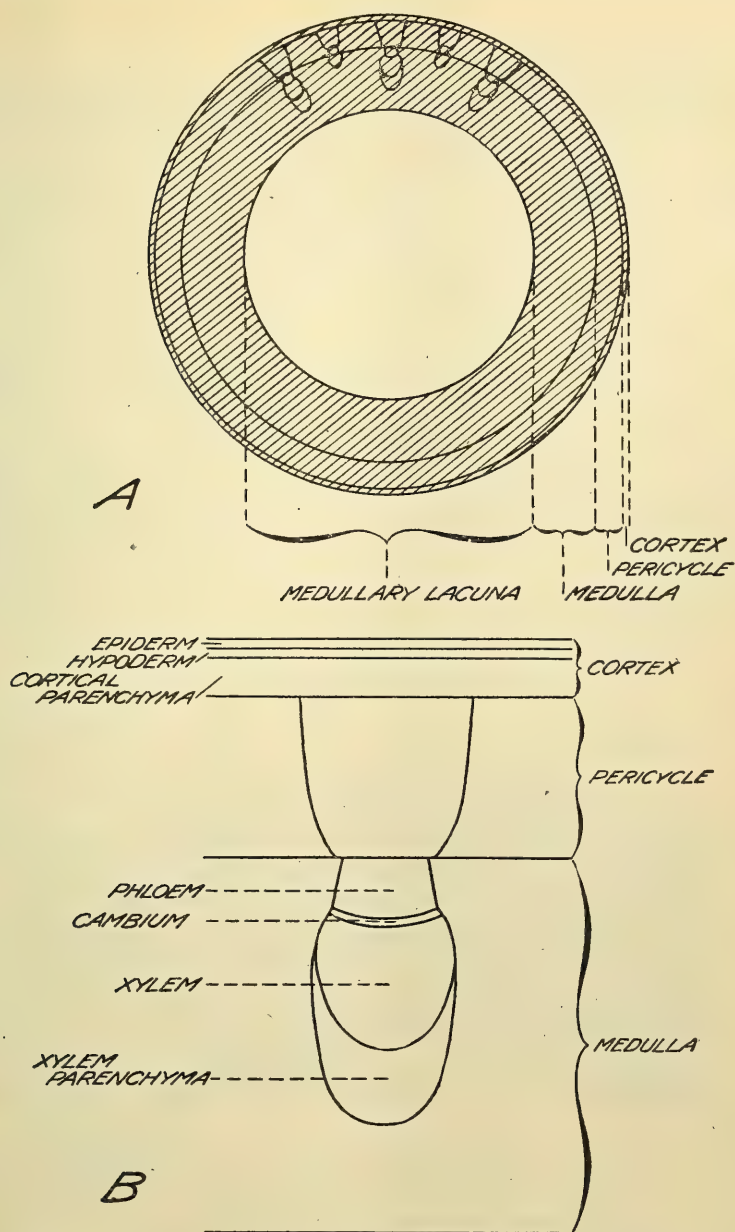


FIG. 2.—A. Diagram of cross-section of stem of group 2. B. Diagram of fibro-vascular bundle of group 2.

group 2. The xylem parenchyma extends some distance inward from the xylem.

Group 6 is represented by *Delphinium ajacis* (Pl. VI, fig. 2, and fig. 4, *A* and *B*). The stem is circular and has a relatively small medullary lacuna. The bundles are about 46 in number and are of two sizes, the large and small arranged alternately. This is the only group in which it was possible to distinguish a row of endodermal cells. All the cell walls are much thickened, which is a distinguishing characteristic of this group. The shape of the fibrovascular bundles is quite characteristic. The bast is wedge-shaped, composed of cells whose walls are so thickened that the lumen is reduced almost to a point. The phloem is small and completely inclosed by the bast and xylem. The xylem mass is larger than the bast, elongated, and includes a large amount of xylem parenchyma.

Delphinium consolida is similar to *D. ajacis*, but the bundles are less numerous, the cell walls in the pericycle are thickened still further, and part of the cells of the cortical parenchyma have thickened walls.

Any of the species which were examined could be quite easily placed in one of the above groups, but within the groups the work thus far done has not revealed sufficiently characteristic differences in stem structure to make identification of species possible. Vesque, 1881, page 29, says that while it is impossible to distinguish genera by anatomical characters, it is easy to distinguish species, but he uses different characters to differentiate the species, such as the structure of the petiole, the development of palisade cells, and the distribution of stomata in the leaf. On the other hand, the present work is based on stem characters, which serve to differentiate between genera in the family Ranunculaceæ, and in this case between groups of species in the genus, but not between individual species. An exception to this is group 6, of which we have only two species in America, and these two can be distinguished by the anatomy of the stem. These two are European species which have been introduced into the United States, and are described anatomically by Lenfant (1897, pp. 26-27, Pl. VII) and Marié (1885, pp. 117-118, Pl. VI). The specimens of *ajacis* and *consolida* from the National Herbarium which were examined had evidently been misnamed, one for the other, as was discovered by comparing cross sections of the stems with the descriptions and figures of Marié and Lenfant.

Sections were also made of two species of *Aconitum*, *A. bakeri* Greene (Pl. VI, fig. 3; and fig. 5, *A* and *B*) and an unidentified species from California, in order to compare them with and to differentiate them from the tall larkspurs. The cross section of the stem shows a structure similar to that of the tall larkspurs, but it can be easily distinguished by the lack of a medullary lacuna, and by the complete

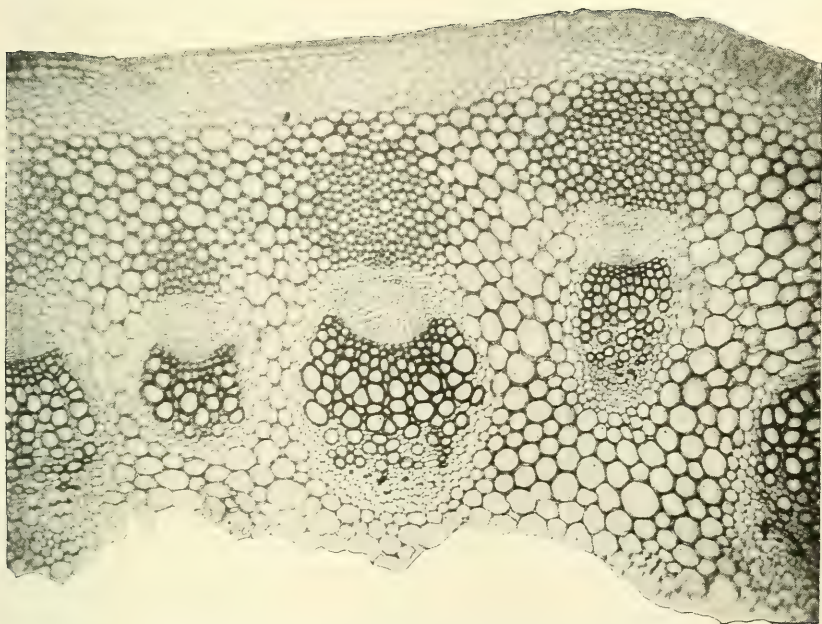


FIG. 1.—CROSS SECTION OF STEM OF DELPHINIUM BARBEYI.

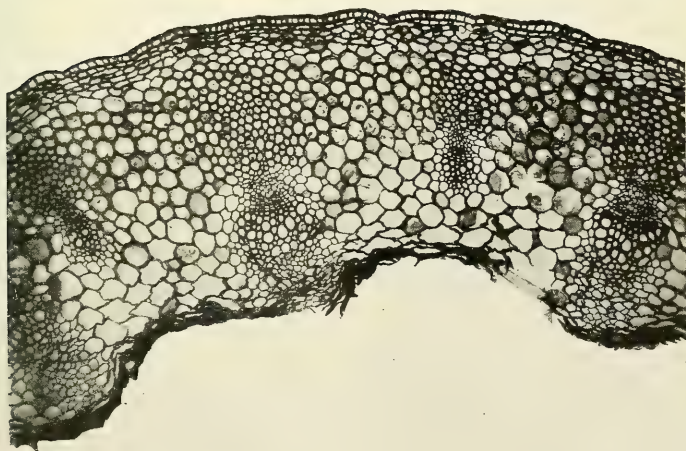


FIG. 2.—CROSS SECTION OF STEM OF DELPHINIUM MENZIESII.

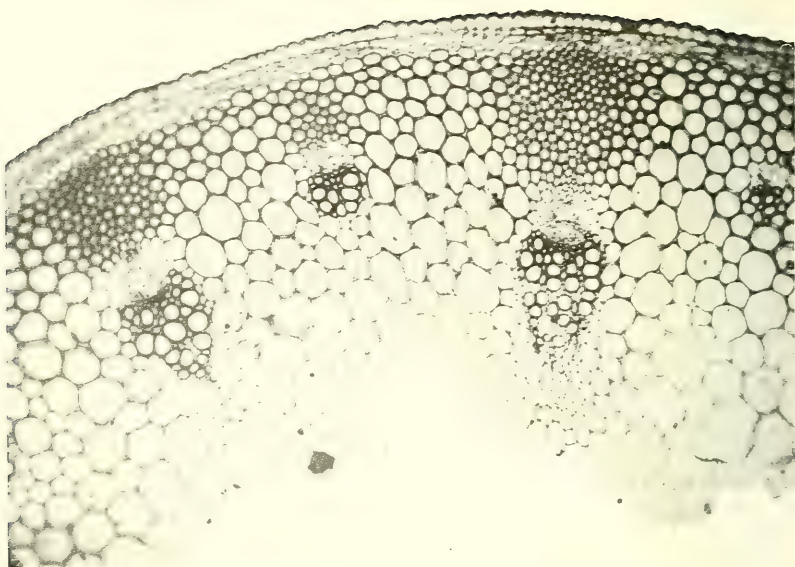


FIG. 1.—CROSS SECTION OF STEM OF DELPHINIUM CARDINALE.

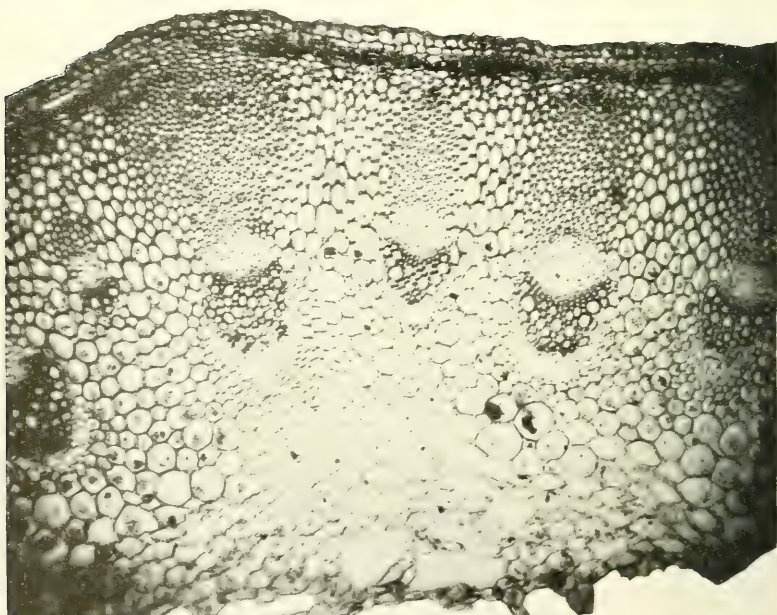


FIG. 2.—CROSS SECTION OF STEM OF DELPHINIUM GEYERI.

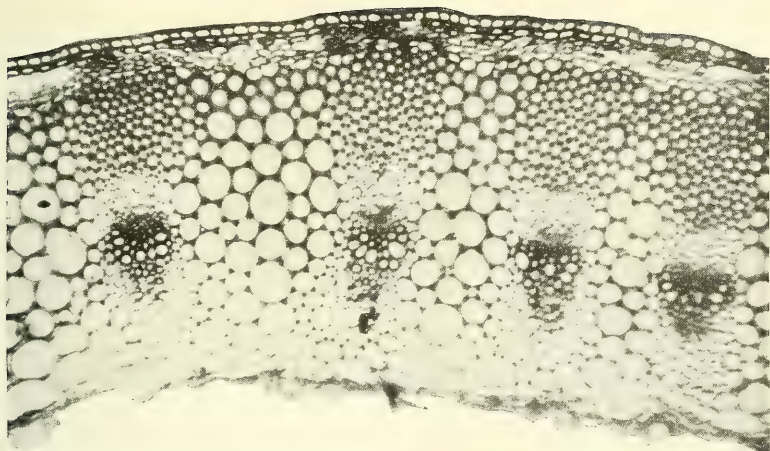


FIG. 1.—CROSS SECTION OF STEM OF DELPHINIUM RECURVATUM.

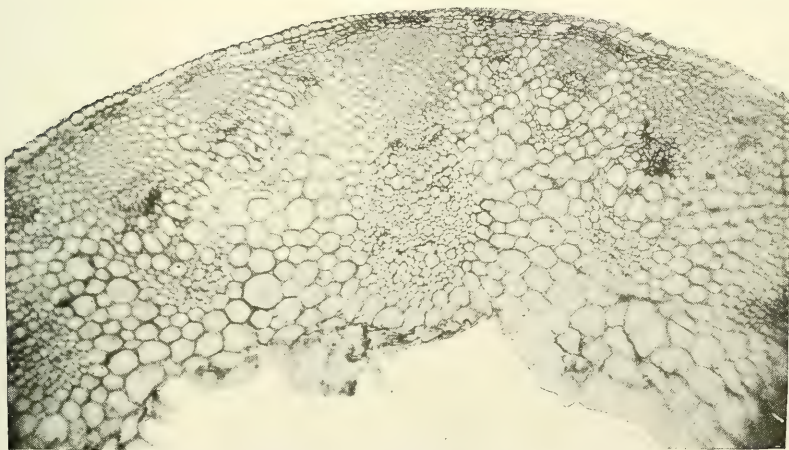


FIG. 2.—CROSS SECTION OF STEM OF DELPHINIUM AJACIS.

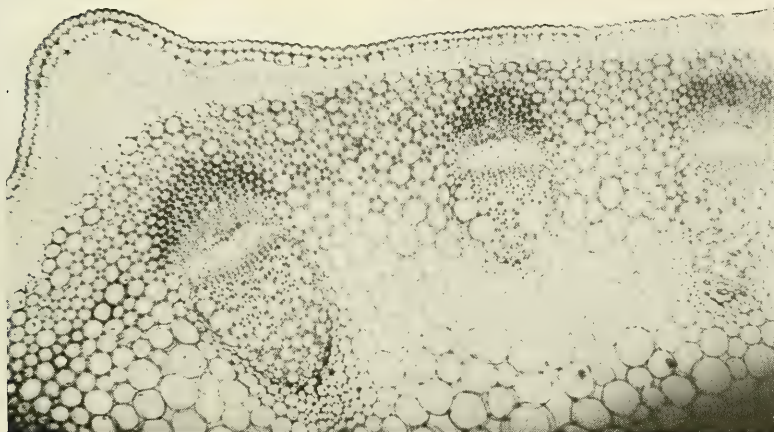


FIG. 3.—CROSS SECTION OF STEM OF ACONITUM BAKERI.



FIG. 1.—STATION AT MOUNT CARBON, COLO.



FIG. 2.—STATION AT GREYCLIFF, MONT.

ring of sclerenchyma outside the bast fibers. As is shown in the diagram (fig. 5), the circumference of the stem is circular, with the

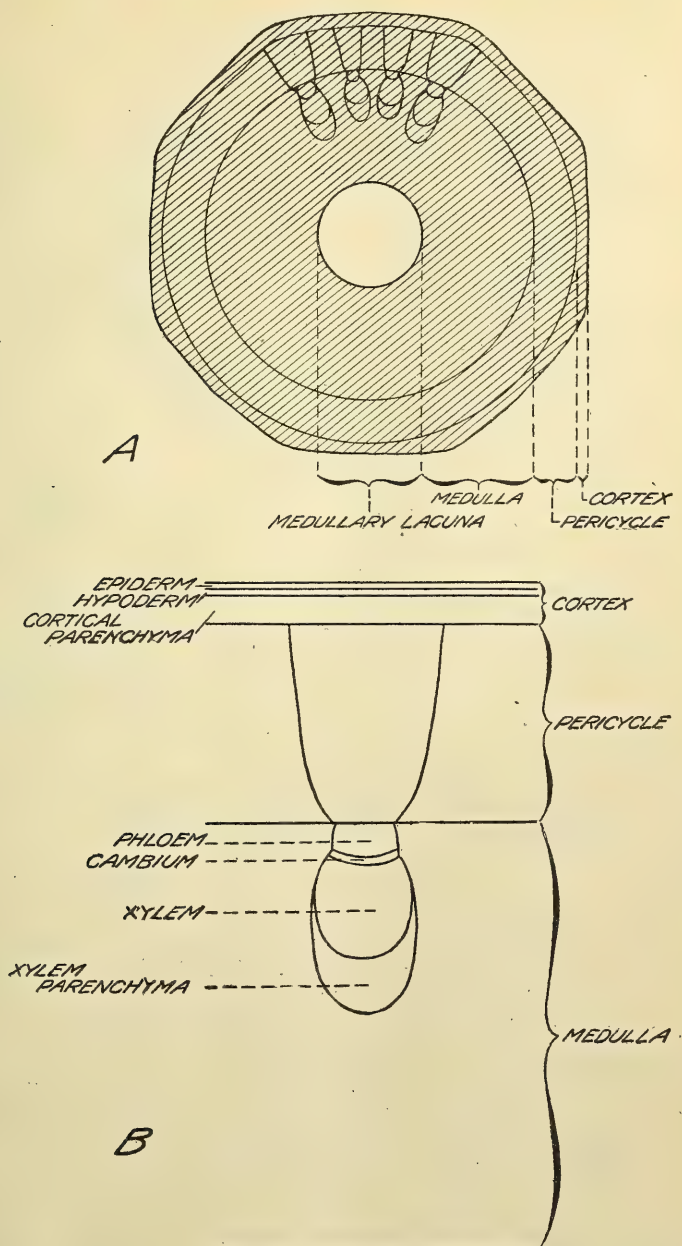


FIG. 3.—A. Diagram of cross-section of stem of group 5. B. Diagram of fibro-vascular bundle of group 5.

exception that at two points the cortex is thickened. The bundles are of about the same size, and about 30 in number arranged in a single

circle. The pericycle is similar to that of *Delphinium*, but is distinguished by the fact that there are several layers of thick-walled

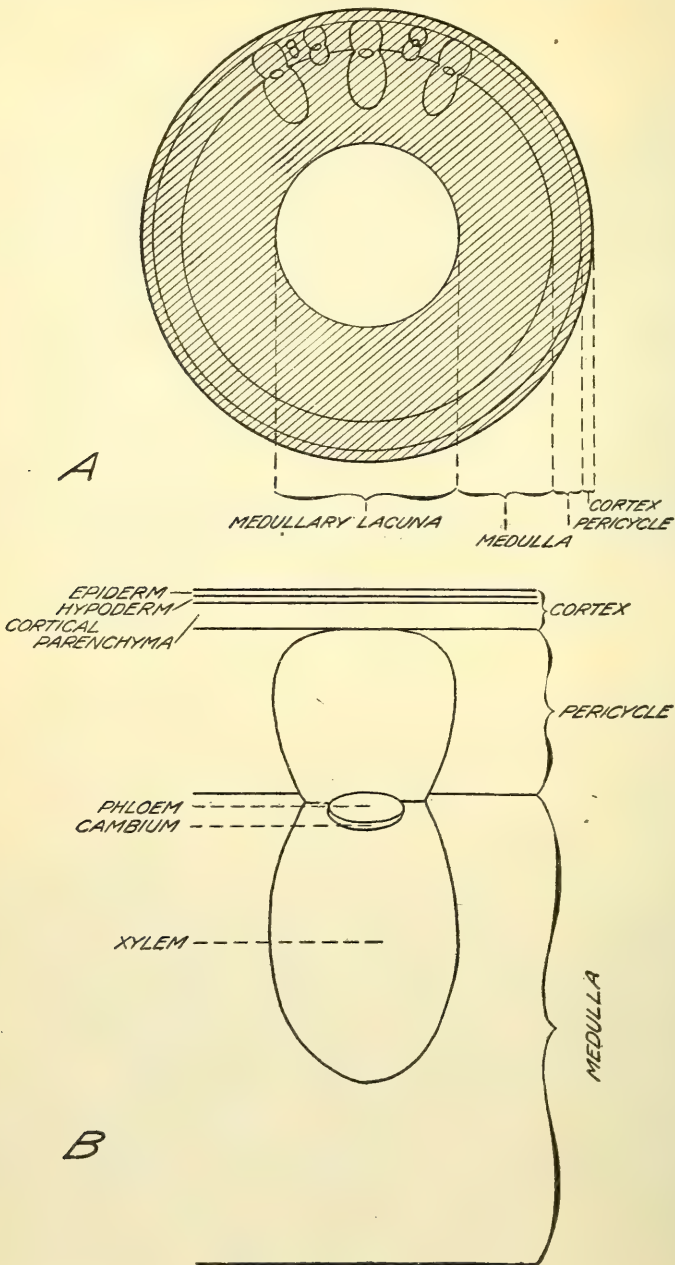


FIG. 4.—A. Diagram of cross-section of stem of group 6. B. Diagram of fibro-vascular bundle of group 6

cells continuous with the interfascicular sclerenchyma, separating the bast from the cortex. The cross section of the fibrovascular

bundle is similar in size and shape to that of the Delphinium group 1. The bast is smaller and crescent-shaped, while the xylem is long and

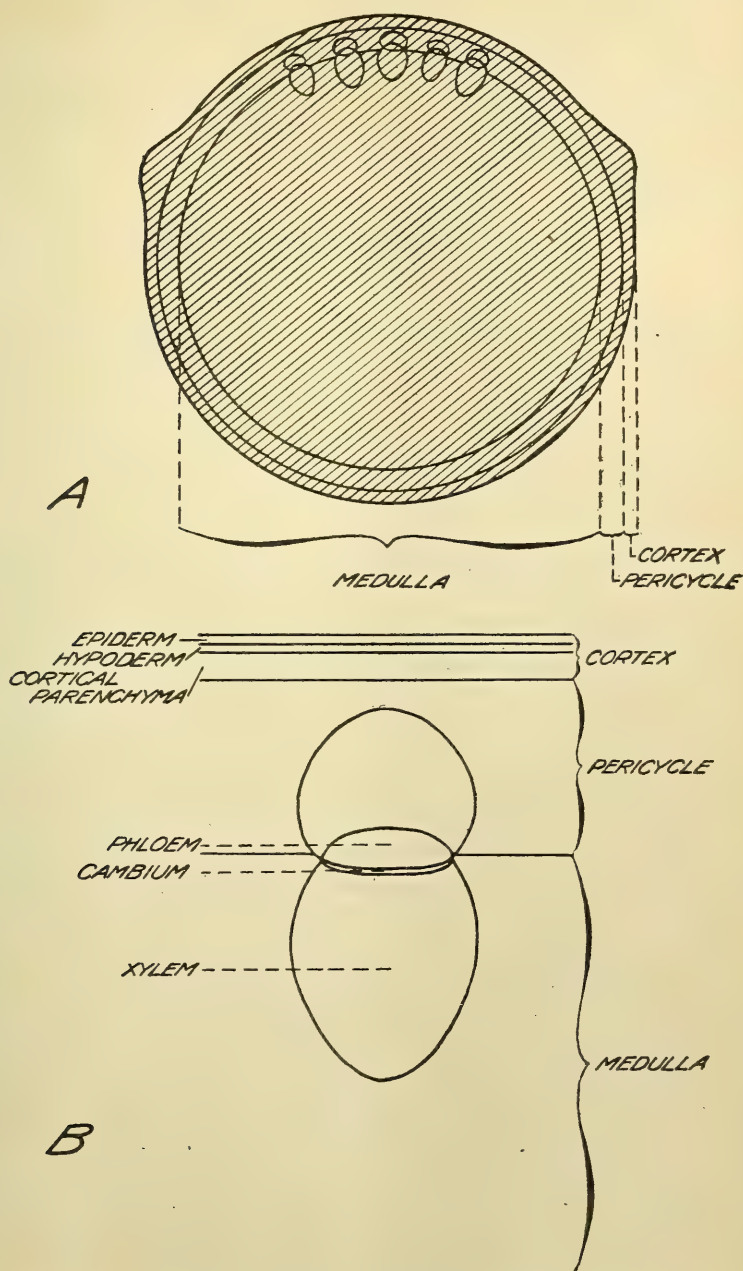


FIG. 5.—A. Diagram of cross-section of stem of Aconitum. B. Diagram of fibro-vascular bundle of Aconitum.

pointed. The outer border of the xylem is only slightly curved and does not inclose the phloem.

As a result of the study of the stem structure of 30 species of *Delphinium* and 2 species of *Aconitum* it has been found possible, by an examination of cross sections of the stems, to distinguish between *Delphinium* and *Aconitum* and between six groups of species in the genus *Delphinium*. This has been put to practical use in the examination of the contents of the rumen of poisoned cattle, by which means it has been possible to determine whether the animal had eaten *Delphinium*, and to which group of species the plant eaten belonged.

PART II.—EXPERIMENTAL WORK.

THE STATION AT MOUNT CARBON, COLO.

The station for the detailed study of larkspur poisoning was located four miles north of Mount Carbon village, in Gunnison County, Colo. (Pl. VII, fig. 1). Through cooperation with the Forest Service, a ranger's station, including a cabin, barn, corrals, and pastures, was provided for the experimental work. This station was in the Ohio Creek Valley at an elevation of about 9,000 feet, in a region where *Delphinium barbeyi* and *Delphinium menziesii* were extremely abundant. In this region, also, losses which are attributed to larkspur occur every year to a greater or less extent, and in some years the losses have been very heavy. This station was selected, too, because it was a favorable location from which studies could be made upon a number of other plants supposed to be poisonous. It was intended, however, that the principal experimental work should be upon these two species of larkspur. The station was equipped with the necessary laboratory facilities, and arrangements were made for cattle and horses for experimental purposes, the work being inaugurated on June 10, 1909, and continuing through that summer until October 1. In 1910 and 1911 it was resumed about the middle of May, and continued until nearly the 1st of October. During these seasons experimental work was conducted upon cattle, horses, and sheep. Acknowledgment should be made to the Forest Service not only for the assistance rendered by equipping the station, but for the continual help of the officers of the Service during the progress of the experimental work. It is desired also to acknowledge the assistance rendered by the stockmen who had cattle upon the Castle Creek and Anthracite ranges. Through the courtesy of these men a large number of cattle were loaned for the experimental work, and thus much material assistance was rendered. While the experimental work was going on the force kept in close touch with the men controlling the cattle upon the ranges, and one or more members of the station force accompanied the stockmen during the time the cattle were driven from the Castle Creek range to the Anthracite range,

in order to be present at the times when larkspur poisoning was deemed most likely to occur. The location of the station was most favorable, not only because of the abundance of larkspurs in the immediate vicinity, but because it was located in the immediate neighborhood of the summer ranges of the cattle, so that a most intimate knowledge of range conditions could be gained.

THE STATION AT GREYCLIFF, MONT.

In 1912 and 1913 the field experimental work in poisonous plants was carried on at Greycliff, Mont. (Pl. VII, fig. 2). An old sheep-shearing plant was loaned for the purpose by the owner, Ole Birke-land, and the necessary repairs were provided by the Forest Service, including fitting up the house for use as office, laboratory, and dining hall, necessary repairs to the barn, and construction of fences and corrals.

While experimental work was to be undertaken on a number of poisonous plants, this location was considered especially favorable for the study of the effects of feeding *Delphinium cucullatum* and *Delphinium bicolor*. The main industry in this region is sheep grazing, and it was considered an especially favorable point to study the effect of the Montana species of larkspur on sheep. Here, as in Colorado, the stockmen of the neighborhood showed most helpful interest in the work and assisted materially by loaning sheep and cattle for experimental work.

EXPERIMENTAL FEEDING OF DELPHINIUM BARBEYI TO CATTLE IN 1909.

In 1909, 42 experiments were conducted of feeding *Delphinium barbeyi* to cattle on 26 different animals. Table I gives a summarized statement of these feeding experiments. The work was not commenced until the last of June and definite results were not obtained until the last of July. Of these 42 cases 22 were poisoned.

As the season progressed it was evident that larger quantities of the plants were necessary to produce toxic effects than had been supposed at the beginning of the experiments, and this fact doubtless explains the failure to produce poisoning in the earlier experiments. The summarized results in regard to symptoms and treatment are given later in this paper. Following are a few typical cases given in some detail.

CASE 92.

This case was interesting as being the first one in which there were definite symptoms of poisoning. Case 92 was a cow weighing about 990 pounds which had been used for experimental purposes with *Delphinium menziesii* without any effect. On June 30 she ate 30 pounds of leaves and stems of *Delphinium barbeyi*. On the

TABLE I.—Summary of feeding experiments upon cattle with *Delphinium barbeyi*, 1909.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of animal weight.	Location from which plant fed was obtained.
	Pounds.	Pounds.						Pounds.	
84	740	7.5	June 28-29	Leaves and stems.	Not known.	Potassium permanganate.	Recovery.	10.1	Near station.
92	990	30	June 30	do.				30	Do.
113	750	26.5	July 2-3	do.				35.3	Do.
81	1,230	6	July 8-9	Leaves, stems, and flowers.				4.6	Do.
112	610	17.7	July 10-11	do.				18.8	Do.
91	980	16.5	July 17	do.				16.8	Do.
92	990	22.5	July 25-27	Leaves, stems, flowers, and seed.	1 hour.	Potassium permanganate.	Recovery.	50	Do.
605	450	12	July 30-31	do.	35 minutes.	Caffeine and potassium permanganate.	do.	26.6	Do.
605	450	9.5	Aug. 1	do.	12 hours.		do.	21.1	Do.
			do.						
97	500	35	Aug. 1-3	Leaves, stems, and seed.	Death.	Atropin, caffeine, and potassium permanganate.	Death.	70	Do.
603	550	34	Aug. 2-4	do.	2½ hours.	Atropin, caffeine, and potassium permanganate.	Recovery.	61.8	Do.
602	450	25	Aug. 5-6	Flowers, seed, and seed stems.	3½ hours.	Atropin, caffeine, and paunched.	do.	55.5	Do.
606	450	28	do.	Leaves and stems.				52.2	Do.
107	420	9	Aug. 7-10	Seed and seed stems.				21	Do.
108	430	14.75	do.	Leaves and stems.				34.3	Do.
98	460	14.75	Aug. 10-11	Flowers.				32.1	Kebler Pass.
82	960	63.75	Aug. 10-12	Leaves and stems.	45 minutes.	Atropin, caffeine, and paunched.	Recovery.	66.4	Kebler Pass and near station.
117	620	32.25	Aug. 13	Leaves, stems, flowers, and seed.	13 hours.	Atropin, caffeine, and potassium permanganate.	do.	52	Kebler Pass.
113	750	23	Aug. 13-14	Seed and seed stems.				30.7	Near station.
112	610	38	do.	Leaves and stems.				62.3	Kebler Pass.
92	990	27.5	do.	Seed and seed stems.				27.7	Do.
115	610	63.5	Aug. 17-19	Leaves, stems, flowers, and seed.	2½ hours.	Potassium permanganate.	Recovery.	104	Do.
604	450	11.75	Aug. 17-21	Seed and seed stems.	1½ hours.	Caffeine.	do.	187.7	Near station. Kebler Pass.
608	700	113.25	do.	Leaves, stems, flowers, and seed.	40 minutes.		do.	161.8	Kebler Pass.
603	550	95.75	Aug. 19-22	Leaves and stems.	2 hours.		do.	174	Do.
112	610	34.25	Aug. 19-20	Seed and seed stems.	30 minutes.	Atropin.	do.	56.1	Do.
108	430	22.75	Aug. 24-25	Leaves and stems.	Sick but not down.		do.	52.9	Do.
98	460	48	do.	Leaves, stems, and seed.	2 hours.		do.	104.3	Do.

107	420	50.5	Aug. 24-27	do	4 hours	Magnesium sulphate	do	120.2	Do. Pass and
81	1,230	161.25	Aug. 27-Sept. 4	do	Death		Death	131.1	Kebler Pass near Salt Lick.
605	450	29.5	Aug. 28-29	Seeds and seed stems	5 hours	Caffein	Recovery	65.5	Do.
606	450	195	Aug. 28-Sept. 4	Leaves and stems		Magnesium sulphate		433.3	Do.
113	750	32.75	Sept. 2-4	Seed and seed stems				43.6	Kebler Pass in part.
113	750	60.5	Sept. 9-10	do	2 hours	Atropin	Recovery	10	Kebler Pass.
602	450	388.25	Sept. 9-16	Leaves, stems, and seed		Magnesium sulphate		862.8	Do.
608	700	280.5	do	do				400.7	Near station and near Salt Lick.
112	610	79.5	Sept. 16-17	do	Death		Death	130.3	Kebler Pass.
84	740	292.25	Sept. 16-23	do				394.8	Salt Lick and above Cokeovens.
92	990	316	Sept. 18-25	do				319.2	West side of Mt. Carbon.
98	460	357.25	do	do				776.6	Kebler Pass.
115	610	132	Sept. 25-28	do		Magnesium sulphate		216.4	Do.

morning of July 1 it was noticed that she staggered as she walked, her hind legs appearing stiff. She gave evidence also of some abdominal pain. This peculiar stiffness in gait continued through the day of July 1 and was still noticeable on the morning of July 2. No other pronounced symptoms of poisoning were noticed.

CASE 605.

Case 605 was a yearling heifer loaned for experimental purposes by Mr. J. H. Eilebrecht. She was estimated to weigh about 450 pounds.

During July 30 and 31 she received 35 pounds of *Delphinium barbeyi*, the material including stems, leaves, and some flowers and seeds. This material was chopped up and mixed with chopped hay in order that the animal might eat it more readily. She was fed at 5 p. m. on July 31 and was apparently entirely normal. At 5.30 it was noticed that she appeared somewhat weak upon her hind legs when forced to walk about the corral. She soon fell, her fore legs giving away first, and she was unable to get up. She moaned as though in pain. Several times she tried to get up but apparently did not have sufficient strength. Her pulse at this time was 60, her temperature 102.2° F. There was no evidence of bloating. At 6 p. m. respiration was 70 and rather irregular. The pulse was slower than when observed before. At 6.11 she suddenly got upon her feet and walked away. She was weak and staggered but otherwise seemed all right. No further symptoms were noticed during that evening.

It was noticed that during this illness she urinated rather freely. She appeared well on the morning of August 1 and the feeding was resumed, giving her as before stems and leaves of *Delphinium barbeyi* with some flowers and seed, the material being cut up and fed with hay. During the forenoon she ate 12 pounds of this material. At 1.15 p. m. while walking about in the corral she suddenly fell and was unable to rise. The pulse was 68, respiration 68 and somewhat irregular. She was constipated and moaned as though in pain. At 1.25 her temperature was 102.3. At 1.30 she suddenly got upon her feet, ran around the corral, and fell down again. At 1.45 her pulse was 60 and respiration 45. At 1.50 she got upon her feet. She stumbled as she attempted to rise, but did not go down again. When started up she stumbled and fell upon her knees, but was able again to get upon her feet. As she stood, the abdominal muscles contracted as if she were in great pain and there was also spasmodic twitching of the muscles of the shoulders.

She remained on her feet after this time and as she appeared normal the feeding was resumed at 3 p. m. She ate 9½ pounds. At

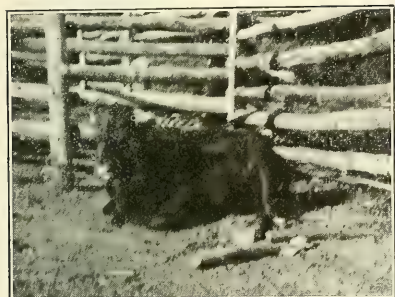


FIG. 1.—CASE 603 AT 4.45 P. M.,
AUGUST 21, 1909.



FIG. 2.—CASE 603 AT 4.54 P. M.,
AUGUST 21, 1909.



FIG. 3.—CASE 603 AT 4.54 $\frac{1}{4}$ P. M.,
AUGUST 21, 1909.



FIG. 4.—CASE 603 AT 4.54 $\frac{1}{2}$ P. M.,
AUGUST 21, 1909.



FIG. 5.—CASE 603 AT 4.54 $\frac{3}{4}$ P. M.,
AUGUST 21, 1909.

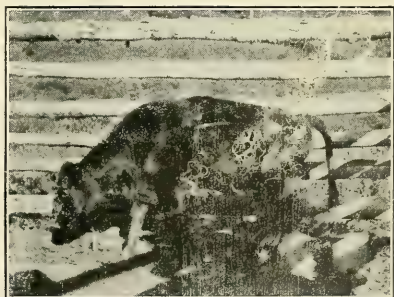


FIG. 6.—CASE 603 AT 4.58 P. M.,
AUGUST 21, 1909.



FIG. 1.—CASE 603 AT 4.58½ P. M.,
AUGUST 21, 1909.



FIG. 2.—CASE 603 AT 4.59 P. M.,
AUGUST 21, 1909.



FIG. 3.—CASE 603 AT 5.15 P. M.,
AUGUST 21, 1909.



FIG. 4.—CASE 603 AT 5.15¼ P. M.,
AUGUST 21, 1909.

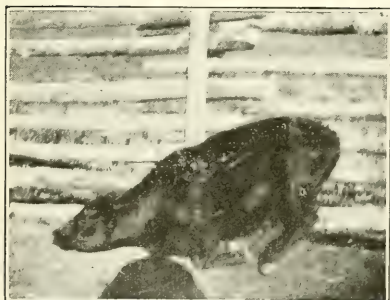


FIG. 5.—CASE 603 AT 5.15¾ P. M.,
AUGUST 21, 1909.

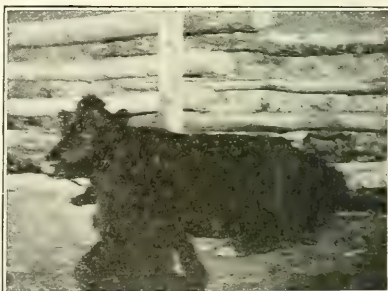


FIG. 6.—CASE 603 AT 5.16 P. M.,
AUGUST 21, 1909.



FIG. 1.—CASE 117 SHOWING HIND LEGS BRACED APART IN THE EFFORT TO REMAIN STANDING.

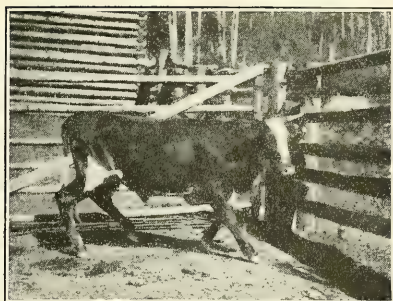


FIG. 2.—CASE 117, AUGUST 15, STAGGERING.

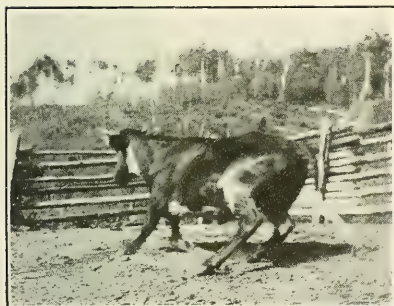


FIG. 3.—CASE 117, AUGUST 15, REMAINING ON ITS FEET WITH GREAT DIFFICULTY.

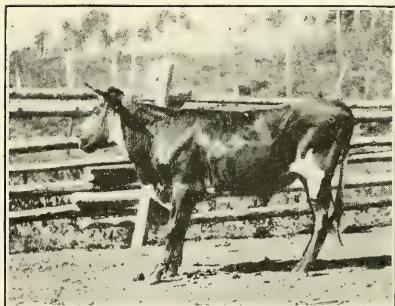


FIG. 4.—CASE 117, AUGUST 15, IN THE ACT OF BACKING IN THE MANNER CHARACTERISTIC OF LARKSPUR POISONING.

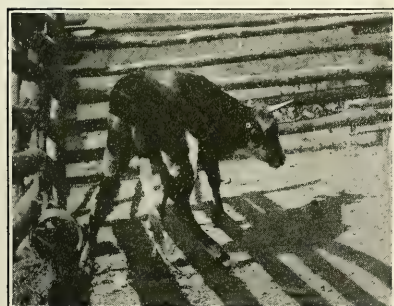


FIG. 5.—CASE 117, AUGUST 15, JUST BEFORE FALLING.



FIG. 6.—CASE 117, AUGUST 15, FALLING IN THE MANNER TYPICAL OF LARKSPUR POISONING.

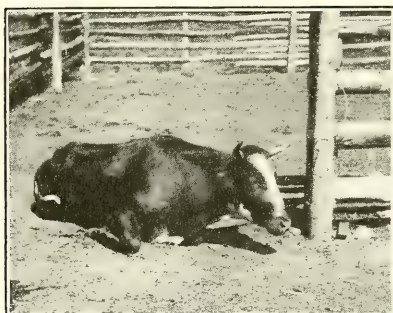


FIG. 1.—CASE 117, AUGUST 15, JUST AFTER AN ATTEMPT TO RISE.



FIG. 2.—CASE 117, AUGUST 15, 9.10 A. M., ATTEMPTING TO RISE.



FIG. 3.—CASE 117, AUGUST 15, 9.35 A. M., AGAIN ATTEMPTING TO RISE.

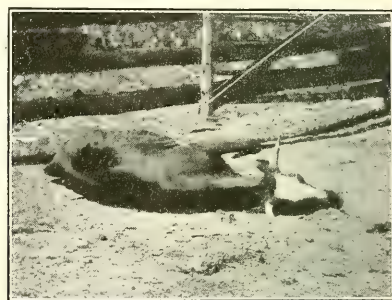


FIG. 4.—CASE 117, AUGUST 15, 10 A. M., UNABLE TO MOVE.

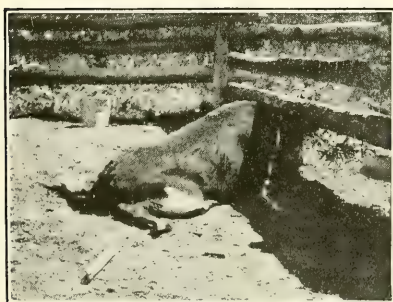


FIG. 5.—CASE 117, AUGUST 15, 12.05 P. M.

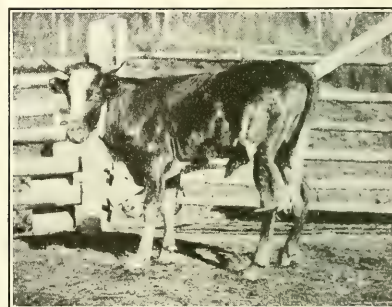


FIG. 6.—CASE 117, AUGUST 17, AFTER RECOVERING FROM POISONING.

6.50 p. m. she was found down again and unable to rise. She was moaning as if in pain. At 7.20 her pulse was 65, and at 10.45 it was 60 and somewhat stronger. She remained down during the night unable to rise, but at 6.45 a. m., on the following morning, she got upon her feet, moved about and although she fell, was able to rise again. A little later, however, she stumbled and fell and could not rise, but at 8.15 a. m. she was again upon her feet and eating as though hungry. At 10.15 a. m. she appeared quite well, with the exception of some weakness, and was turned back into the pasture with the other animals.

During the first of this series of illnesses she was given a drench of potassium permanganate, the treatment being repeated in the evening. There seemed to be no reason, however, to think that this had any definite effect. She was also given hypodermically an injection of 25 grains of caffein sodio-benzoate at 10.45 in the evening. There was no evidence that this produced any effect. This case was particularly interesting because of the successive illnesses produced by renewed feeding of the *Delphinium barbeyi*.

CASE 603.

Case 603 was a yearling heifer, weighing about 550 pounds, which was loaned to the station for experimental purposes by Mr. O. E. Wiseman. From August 2 to August 4 she received 34 pounds of *Delphinium barbeyi*, including stems, leaves, flowers, and buds. This was mixed with hay and corn chop in order that it might be eaten with greater readiness. No effects were noticed until the afternoon of August 4. She was apparently well at 4.30. At 6.50 she was found lying flat on her side and at first was supposed to be dead. She was breathing, however, and soon kicked a little. A dose of 1 grain of atropin was administered subcutaneously. She was raised up so that she lay upon her belly with her head off the ground. In this position she held her head around by her side as if in pain. At 6.55 respiration was 24 and the pulse between 75 and 80 and weak. At this time she was given a drench of potassium permanganate. At 7.03 respiration was 23 and temperature 101.2° F. At 7.15 a hypodermic injection of 30 grains of caffein sodio-benzoate was given. At 7.30 the temperature was 101.3° F. At 7.45 she attempted to get upon her feet but was unable. At 8.20 respiration was 22, pulse about 90 and not very strong. At 9.10 she was upon her feet and from this time showed no further symptoms of poisoning.

She was brought into the corrals for further feeding on August 18. Between August 19 and August 22 she ate 95.75 pounds of *Delphinium barbeyi*, the material including stems and leaves. At 4.35 on August 22 she was found lying with her head turned to the right of the body. She got up, staggered about and fell, but lay with head

erect. At 4.54 she began to walk about uneasily, staggering, and finally fell, going down upon her forefeet first, with her head extended upon the ground.

Plate VIII, figure 1, shows her attitude while lying down at 4.45, and figures 2, 3, 4, and 5 show successive attitudes taken by the animal during the minute from 4.54 to 4.55; figure 2 shows her with arched back and lowered head, in the attitude she took while staggering about the corral; figure 3, taken immediately after, shows very nearly the same attitude; while figure 4 shows her after coming down upon her fore legs, with head extended upon the ground in an attitude which is very characteristic of animals poisoned by larkspur; figure 6 shows her again upon her feet at 4.58. At 4.58 she commenced to stagger, and was upon the ground at 5 o'clock. Plate VIII, figure 6, and Plate IX, figures 1 and 2, show her successive attitudes in this process. She arose again at 5.14, but fell almost immediately. Plate IX, figures 3, 4, 5, and 6, show her attitudes at this time, and it will be noticed that they are comparable with the two preceding series. These four pictures were taken within less than a minute. At 5.26 she was again upon her feet, but at 5.30 commenced to stagger, backing around the corral in a way that was found to be characteristic of larkspur-poisoning cases. She attempted to defecate, moving her head up and down as if in great distress, and then fell down again. She was upon her feet again at 5.44, but at 5.53 fell. Her respiration at this time was 30. At 6 o'clock she was again upon her feet, but moved her head up and down, stepping about uneasily, backing as before. She staggered somewhat, reminding one very much of the actions of a drunken man. At 6.04 she lay down, but at 6.07 got up with no apparent difficulty and began picking up hay in the corrals. At 6.15 she showed uneasiness, moving her head up and down. Then she lay down again. During this latter time she went down voluntarily and was evidently improving, for during the earlier stages of the poisoning she was entirely unable to get upon her feet after falling. At 7.15 she seemed normal, and no further symptoms of poisoning were noticed.

During this case of poisoning there was an interval of two hours from the time the animal first fell until the time when she was able to remain standing.

CASE 117.

Case 117 was a steer weighing about 620 pounds. On August 13 he was fed stems, leaves, and flowers, and a few seed pods of *Delphinium barbeyi*, receiving 32.25 pounds.

On the morning of August 14, at 8.30, it was noticed that he was acting in a somewhat abnormal manner. When walking he kept

upon his feet with difficulty, his legs being too weak to hold him up. Some of the time when standing he would tremble, and at times he would place his legs wide apart as if to keep from falling over. This was particularly noticeable as he walked down hill. Sometimes in walking he would stagger to one side or the other. It was noticed that he urinated quite frequently but the quantity was not great. At 10.30 he seemed to be stronger upon his legs and no marked change was noticed during the rest of the day. Several times he was found lying down but was able to get up without much difficulty.

As showing his weakness it was noticed that when he swung his head around to brush off flies the movement would cause a loss of balance so that he would stagger and almost fall.

Plate X, figures 1, 2, 3, and 4, show some of the attitudes assumed by him during the day. When first seen on the morning of August 15, between 6 and 7 o'clock, his condition did not seem to be changed from that noticed on the preceding day. He was upon his feet and moving about a little. At 8.15 he seemed much weaker. He was down and made no effort to get up. Even with assistance, he was unable to raise the fore part of the body. Plate X, figures 5 and 6, show his attitude at this time; in figure 5 he was trying to hold himself upon his feet while in figure 6 he was falling again. At 8.25 he was given a drench of potassium permanganate. His heart action was very weak at this time and it was with great difficulty that his pulse could be detected. Respiration seemed normal, although his breathing apparently caused pain. At 8.30 he was given subcutaneously 1 grain of atropin dissolved in camphor water. A little after this he tried to get up but was unable. He could not get his forequarters off the ground, but did succeed in moving himself around. Plate XI, figure 1, shows him just as he had fallen back after an attempt to get upon his feet. During the rest of the day he made several attempts to get up but was generally unable to raise his hindquarters from the ground. It was evident that he was in constant pain and this forced him to attempt to change his position. At 9.55 a. m. his pulse was about 95, his respiration 36. The pupils were very much dilated from this time on, probably from the influence of the atropin. There were spasmodic contractions of the abdominal muscles.

Plate XI, figure 2, shows the animal attempting to get up at 9.10; figure 3 shows him at 9.35 when he was attempting without success to get up. The abdominal pain was apparently very severe. At 10.30 he was given subcutaneously 25 grains of caffein sodio-benzoate. At 10.40 his temperature was 102.4° F. Plate XI, figure 4, shows his attitude at 10 a. m. and figure 5 shows him at 12.05, noon. At 2.45 he seemed weaker than at any preceding time and the pulse was hardly perceptible. He was given 1 grain of atropin in cam-

phor water. At 3.25 the pulse was fairly strong. At 4.25 he very nearly succeeded in getting upon his feet. The muscles of the shoulders and flanks were trembling much of the time.

As he was much constipated, feces being discharged only once during the day, he was given at 6 p. m. 12 ounces of Epsom salt as a drench. At 9.10 p. m. he appeared very much brighter than at any time during the day. Trembling was not so pronounced and the pain was less. He breathed normally, held his head from the ground and took notice of what was passing around him. He was not seen again until the morning of August 16. At 6.45 a. m. on August 16 he got up, ate a little hay and drank water. During the forenoon of August 16 he lay down most of the time but occasionally got up and walked from place to place. The improvement continued during the afternoon and night. He still staggered when walking and remained upon his feet only a few minutes, but could get up and down at will. On the morning of August 17 there was still some trembling of the surface muscles of the shoulders. Plate XI, figure 6, was taken at 7.25 a. m. on August 17 when he appeared fairly normal.

He was driven back into the pasture still showing weakness, trembling, and staggering when hurried, but after this his recovery was rapid and complete.

EXPERIMENTAL FEEDING OF *DELPHINIUM BARBEYI* TO CATTLE IN 1910.

The experimental feeding of *Delphinium barbeyi* in 1909 had indicated somewhat clearly the symptoms of poisoning and the dosage so that the work of 1910 was largely directed to experiments with various remedies. The discussion of these remedies is taken up later in this paper. Table II gives a summary of the experimental feeding of *Delphinium barbeyi* to cattle during this second summer. Forty-three feeding experiments were conducted on 24 different animals. Following is a detailed description of some of the more typical cases.

CASE 612.

Case 612 was a yearling heifer loaned for experimental purposes and weighing about 500 pounds. From July 2 to July 5 she received 76.5 pounds of *Delphinium barbeyi*, including leaves, stems, and flowers. At 4.15 p. m. on July 5, as the animal had apparently felt no effect from the feeding, an attempt was made to run her about the corral. After being run about a few times she began to tremble, her legs giving out, and she fell and was unable to rise. Respiration was 60 and irregular and the pulse 160 and weak. At 4.20 she fell over upon her side, the surface muscles contracting spasmodically. At 4.24 the pulse was 100 and rather weak. At 4.27 she was given

subcutaneously one-half grain of atropin. At 4.29 the pulse was between 95 and 100, respiration 46 and slower and deeper than when noticed before. At 4.38 respiration was 60 and irregular. At 4.40 the pulse was 75 to 80. At 4.51 respiration was 40 and the pulse 94. At 5.01 she suddenly got up without any apparent effort and walked the length of the corral. She stood for a moment, trembling violently, then fell, going over upon her left side. At 5.30 an attempt was made to get her upon her feet, when she began to vomit. She was held up for about ten minutes, until it was evident that there was no regurgitated material in the lungs or trachea. At 5.55 she attempted to get upon her feet, but was unable. At 6.10 she was given a hypodermic injection of one-fourth grain atropin, and at 6.30 she was given hypodermically 10 cubic centimeters of undiluted whisky. At 6.45 she lay with head extended, eyes partly closed, lips apart, muscles of the flanks twitching, with rapid breathing, and was apparently about to die. At 6.55 she was given a second dose of 10 cubic centimeters of undiluted whisky. At 7.10 her head was raised and she was able to keep it erect. At this time she attempted to get up and made another attempt at 7.12. At 7.22 she got up, went the length of the corral and walked about nervously. There was still some twitching of the muscles of the body. From this time on she seemed to improve in condition and showed no other symptoms of poisoning. There seemed to be no doubt that in this case the injection of whisky had bridged over a period of weakness which otherwise might have ended fatally.

CASE 118.

Case 118 was a yearling steer born August 9, 1909, whose estimated weight was 300 pounds. He received July 7, 18.25 pounds of *Delphinium barbeyi* including stems, leaves, and blossoms. This was given in three feedings, one at 9.15 a. m., one at 9.40 a. m., and one at 2.40 p. m. At 3.55 he was found down and unable to get up, apparently from weakness. At 4 p. m. the pulse was 70 and rather weak, respiration 72. At 4.09 respiration was 100 and pulse 75. Saliva was running from his mouth. At 4.28 the pulse was 60. At 5.01 there were a few spasmodic contractions of the legs, but nothing that could be considered as convulsions. During these spasmodic contractions he went over on his left side and remained there. Respiration was 54. During this time he had made several unsuccessful attempts to rise. There was some belching of gas from the stomach.

Two subcutaneous injections of atropin were given, the quantity given being one-half grain in all. The respiration became more and more shallow and soon stopped entirely. An attempt was made to stimulate it by inhalation of ammonia, but it was unsuccessful.

TABLE II.—*Summary of feeding experiments upon cattle with Delphinium barbeyi, 1910.*

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of live weight.	Location from which plant fed was obtained.
	<i>Pounds.</i>	<i>Pounds.</i>						<i>Pounds.</i>	
98.....	650	19.75	May 30.....	Leaves and stems.....	Death.....	Barium chlorid, caffen, and strychnin.	Death.....	30.4	Near station.
107.....	600	90	June 11-17.....	do.....	do.....	Physostigmin, pilocarpin and strychnin.	do.....	150	Do.
613.....	450	38.5	June 29-July 1.....	do.....	do.....	do.....	do.....	85.5	Do.
612.....	500	76.5	July 2-5.....	Leaves, stems, and flowers.....	3 hours.....	Aurotin and whisky.....	Recovery.....	153	Do.
82.....	1,000	101.5	July 6-11.....	Flowers.....	Death.....	Aurotin and alcohol.....	Death.....	101.5	Do.
118.....	300	18.25	July 7.....	Leaves, stems, and flowers.....	9 hours.....	Physostigmin, pilocarpin and strychnin, and whisky.....	Recovery.....	60.6	Do.
610.....	510	20	July 13.....	Leaves, stems, and flowers.....	15 hours and 16 minutes.....	Physostigmin, pilocarpin, and strychnin.	do.....	66.7	Do.
626.....	450	30	July 19.....	Leaves, stems, flowers, and few seeds.....	25 minutes.....	Physostigmin pilocarpin, and strychnin.	Recovery.....	70	Do.
627.....	500	20	do.....	Leaves, stems, and seed.....	.....	.....	.....	.....	Do.
617.....	400	28	July 24.....	Leaves, stems, and flowers.....	.....	.....	.....	.....	Do.
622.....	500	32	July 24-28.....	Leaves, stems, flowers, and seed.....	.....	.....	.....	.....	Do.
628.....	500	46	July 26-28.....	Leaves, stems, and seed.....	.....	.....	.....	.....	Do.
620.....	500	42	July 29-30.....	Leaves, stems, and seed.....	2 hours and 20 minutes.....	Physostigmin, pilocarpin, and strychnin.	Recovery.....	84	Do.
624.....	500	103.5	July 29-Aug. 1.....	Leaves, stems, flowers, and seed.....	16 minutes.....	.....	do.....	207	Do.
621.....	500	31	Aug. 2.....	Leaves and stems.....	41 minutes.....	Physostigmin, pilocarpin, and strychnin.	do.....	62	Do.
614.....	500	45	Aug. 2-3.....	Leaves, stems, and seed.....	47 minutes.....	.....	do.....	90	Do.
609.....	500	27	Aug. 3-4.....	Seed and seed stems.....	Death.....	.....	Death.....	54	Do.
618.....	500	35	Aug. 4-5.....	Leaves and stems.....	27 minutes first day; 30 minutes second day.....	Physostigmin, pilocarpin, and strychnin.	Recovery.....	70	Do.
121.....	300	50	Aug. 4-6.....	Leaves, stems, and seed.....	1 hour and 9 minutes.....	do.....	do.....	167	Do.
625.....	600	168.5	Aug. 4-8.....	Leaves, stems, flowers, and seed.....	17 minutes.....	do.....	do.....	280.8	Kebler Pass.
610.....	500	45.5	Aug. 6-7.....	Leaves and stems.....	14 minutes.....	do.....	do.....	91	Near station.
612.....	500	25.5	do.....	Seed and seed stems.....	40 minutes.....	do.....	do.....	51	Do.

628.....	55.5	Aug. 8-11.....	Leaves, stems, and seed.....	20 minutes first day; 1½ hours second day.	Physostigmin, pilocarpin and strychnin, and whisky.	do.....	111	Do.
622.....	24	do.....	Seed and seed stems.....				48	Do.
627.....	130	Aug. 8-14.....	Leaves and stems.....				260	Do.
619.....	101.5	Aug. 10-14.....	Leaves, stems, flowers, and seed.				233.7	Kebler Pass.
82.....	15.5	Aug. 12-15.....	Seed and seed stems.....				15.5	Near station.
626.....	156.5	Aug. 12-17.....	Leaves, stems, and seed.....				347.8	Do.
617.....	78	Aug. 15-18.....	Seed and seed stems.....				195	Salt Lick and Kebler Pass.
620.....	128.5	Aug. 15-19.....	Leaves and stems.....				257	Salt Lick.
621.....	157	do.....	Leaves, stems, and seed.....				314	Kebler Pass.
622.....	500	Aug. 19-23.....	do.....				233	Salt Lick.
618.....	44	Aug. 20-23.....	Seed and seed stems.....	20 minutes		Recovery	88	Kebler Pass.
625.....	600	do.....	Leaves and stems.....				224	Salt Lick.
624.....	254.5	Aug. 20-25.....	Leaves, stems, seed, and few flowers.				509	Kebler Pass.
121.....	300	Aug. 24-25.....	Seed and seed stems.....	1 hour	Physostigmin, pilocarpin, and strychnin.	Recovery	933	Do.
614.....	354.5	Aug. 24-30.....	Leaves, stems, and seed.....				709	Salt Lick.
619.....	26	Aug. 26-28.....	Seed and seed stems.....				65	Kebler Pass.
627.....	271.5	Aug. 26-31.....	Leaves and stems.....				543	Do.
621.....	291	Sept. 1-7.....	Leaves, stems, and seed.....				582	Salt Lick.
628.....	275.5	do.....	do.....				551	Kebler Pass.
115.....	78	Sept. 9-13.....	do.....				94.5	Salt Lick.
120.....	198	Sept. 9-16.....	do.....				792	Kebler Pass.

Fifty cubic centimeters of alcohol was given subcutaneously about the time respiration stopped, but this was evidently too late. The pulse could be felt for about three minutes after respiration had stopped.

An autopsy was made on the morning of July 8. The heart was found to be in diastole with petechiæ upon its walls. The mucous membranes of the larynx and trachea were inflamed and the lungs congested. The walls of the first stomach were congested near the esophageal opening. The walls of the second and third stomach were strongly congested at the cardiac end. The duodenum was congested, the jejunum slightly congested. The ileum was slightly congested throughout its length. There was congestion in the upper part of the cecum. The walls of the rectum near the anus were extruded and inflamed. The kidneys were congested. It was noticeable in this animal that while there was mucus in the trachea and bronchi there had been no actual vomiting.

CASE 610.

Case 610 was a yearling heifer weighing about 500 pounds which was loaned by the Castle Creek stockmen. She was fed leaves, stems, and flowers of *Delphinium barbeyi* on July 13, being fed at 9, 9.30, and 10 a. m., eating altogether 20 pounds. At 11.40 she became uneasy and soon went down, and by the time the observer could obtain assistance from the laboratory she was found on her left side, flat upon the ground.

She was immediately given a subcutaneous injection of physostigmin salicylate three-fourths grain, pilocarpin hydrochlorid $1\frac{1}{2}$ grains, and strychnin sulphate one-half grain. At 11.45 respiration was 80 and pulse 64. A picture was taken at 11.49, which shows her lying flat upon the ground (Pl. XII, fig. 1). At this time there was some trembling and some salivation and she was kicking about as though in pain. At 11.45 the pulse was 76, respiration 60 and shallow. At 12.11 the pulse was 75. At 12 o'clock a small amount of feces was passed and more at 12.12. There was a further passage at 12.35. From 12 until about 12.30 considerable gas was expelled from the stomach. At 12.30 she was able to raise herself upon her belly. At 12.35 the pulse was 72. It was noticed that there was considerable secretion during this time from the lachrymal glands. By 1.40 considerable gas had accumulated in the rumen, and as she did not seem to be able to relieve herself by expelling it per os, the trocar was thrust into the rumen. This relieved the pressure and the breathing became easier. The animal lay at this time with her head around to her side in the position shown in Plate XII, figure 2.

From 12.30 on it was noticed that she perspired quite freely. This was probably due to the effect of the remedy pilocarpin. At 2



FIG. 1.—CASE 610 AT 11.49 A. M., JULY 13.



FIG. 2.—CASE 610 AT 11.49½ A. M., JULY 13.



FIG. 3.—CASE 612 AT 1.18 P. M., AUGUST 7.

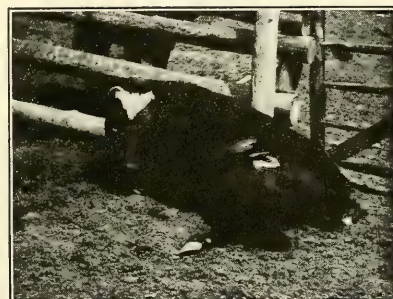


FIG. 4.—CASE 612 AT 1.30 P. M., AUGUST 7.

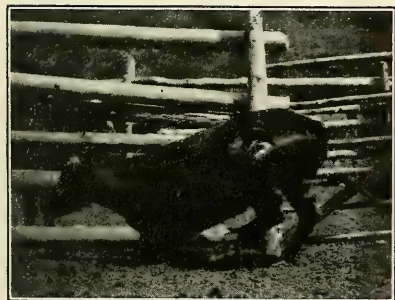


FIG. 5.—CASE 612 AT 1.37 P. M., AUGUST 7.

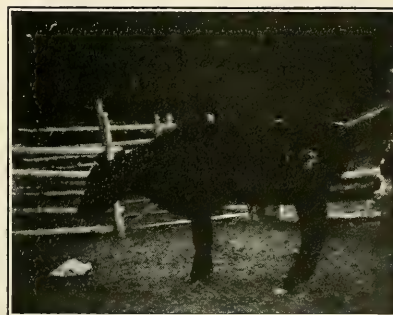


FIG. 6.—CASE 612 AT 1.47 P. M., AUGUST 7.



FIG. 1.—CASE 82 AT 3.20 P. M.

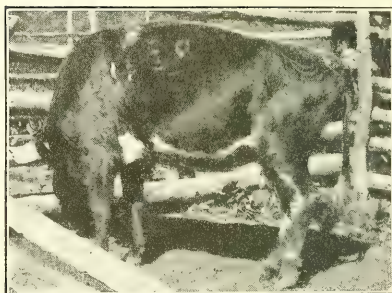


FIG. 2.—CASE 82 AT 3.24 P. M.



FIG. 3.—CASE 82 AT 3.27 P. M.



FIG. 4.—CASE 82 AT 3.56 P. M.



FIG. 5.—CASE 82 AT 3.56 P. M., AFTER
FALLING.



FIG. 6.—CASE 82 AT 3.59 P. M.

o'clock her respiration was 85, deeper and much more regular than before the gas was allowed to escape from the stomach. At 4.06 the pulse was 80 and apparently weaker, respiration 44. At 4.15 as she seemed to be growing weaker she was given a hypodermic injection of 20 cubic centimeters of whisky. At 4.20 respiration was 40. At 4.25 the pulse was 100 and stronger. While, during the afternoon she had seemed stupid, paying very little attention even to the flies which were around her in great numbers, at 4.52 she became sufficiently lively to attempt to get rid of the flies. There was still some twitching of the muscles of the flanks. At 5.43 the pulse was 86 and respiration 28. At 6.40 respiration was 24. She continued down until 8.03 when she was able to get upon her feet. At 8.06 she arched her back with her hind feet apart and trembled all over. She fell down, going over on her side. The pulse was 90 and weak, the respiration seemed normal. At 8.33 she was able to get up again. She had urinated very little and apparently there had been very little urination for a considerable time before her illness. She was also very much constipated. During the night of July 13 considerable urine was passed and some feces. On the morning of July 14 she was still weak and was kept in the corrals until July 15, when she was turned out as recovered.

CASE 612.

Case 612 was brought in for further experimental work on August 1. During August 6 and the forenoon of August 7 she received 25.5 pounds of seeds and seed stems of *Delphinium barbeyi*. At 1.05 p. m. August 7 she was found lying down, but when approached walked away apparently in good condition. At 1.07 her back was arched, she began to tremble, backing around the corral in an uneasy manner, and soon fell, going down upon the forelegs and lying upon the belly. At 1.10 when disturbed there was some muscular twitching of the shoulders. She remained upon her feet until 1.18, when she began to tremble and went down. She lay upon her right side flat upon the ground. Plate XII, figure 3, shows her position at this time. She was rolled over and placed with head erect. At 1.23 her pulse was 80 and weak, respiration 92, and fairly regular. At 1.26 she was given hypodermically physostigmin salicylate, 1 grain; pilocarpin hydrochlorid, 2 grains; and strychnin sulphate, one-half grain.

Plate XII, figure 4, shows her position at 1.30. She had made several unsuccessful attempts to get upon her feet, but at 1.37 was able to get up. Plate XII, figure 5, shows her in the act of rising. She walked across the corral but at 1.38 stumbled and fell again, going over upon her side. At 1.23 respiration was 143. She was

expelling some gas from the stomach. At 1.42 the pulse was 120. At 1.46 the pulse was 104. At 1.47 she raised herself without much effort. Plate XII, figure 6, shows her at this time. At 1.52 she was trembling, her back was arched, and she was stepping about uneasily. There was considerable salivation, and there was and had been for some time dribbling of urine. At 1.55 the trembling was very much decreased. She walked with a stiff gait and at 2.04 seemed to be over the attack. No further symptoms were noted.

EXPERIMENTAL FEEDING OF DELPHINIUM BARBEYI TO CATTLE IN 1911.

Because *Delphinium menziesii* disappears about the first of July, the station work in the early part of the seasons of 1909 and 1910 was very largely concentrated on this plant, and most of the work on *Delphinium barbeyi* was done after the plant was in blossom. As the season in 1911 was about two weeks later than in 1910, *Delphinium barbeyi* in the middle of July in 1911 was in about the same stage of development as at the first of July in 1910. In addition to confirming the work of the preceding seasons on symptoms and remedies, especial attention was paid to the poisonous effects of the plant in its early stages. Two experiments were made of feeding the dried plant, as it was desirable to determine whether the plant lost its poisonous properties by drying.

Twenty-six feeding experiments were conducted on 22 different animals, and the greater poisonous effect of feeding the larkspur within a short period of time was much more clearly brought out than in the preceding seasons.

The experimental work with remedies made it possible to determine quite definitely the quantities of physostigmin, pilocarpin, and strychnin which could be used to the best advantage.

Table III shows the results of the feeding in a summarized form and they are discussed later in the paper. None of the cases are given in detail, since the feeding experiments were conducted in the same manner as in the preceding years and the general results were the same.

EXPERIMENTAL FEEDING OF DELPHINIUM MENZIESII TO CATTLE IN 1909.

During the season of 1909, nine experiments were made of feeding *Delphinium menziesii*, the experiments commencing on June 24 and continuing until July 25. Part of the material used was collected around the station, and was to a large extent mature, the plant being in flower and in some cases containing seeds; the remainder was obtained at Kebler Pass, and consisted of small plants before flowering. The whole plants, including roots, stems, and flowers, were fed to some animals, while in other cases only the tops were fed, and in still others the roots ground up with grain.

It is commonly believed by stockmen that the root of this plant is the most poisonous, and it is generally supposed that the plant produces more cases of poisoning after a rain, because at that time the ground is soft and the animals can pull up the plant by the roots and thus get the part in which the poison is supposed to be concentrated.

Table IV gives a summary of these experimental feedings.

Experiments were made by feeding the roots alone, the animals used being Nos. 92 and 117. Number 92 in two days ate a quantity equivalent to 2.04 pounds per 1,000 pounds of weight, while No. 117 in one day ate 2.1 pounds per 1,000 pounds. The greatest quantity fed at any time was to No. 115, which between July 10 and July 12 received 100.7 pounds of tops, seeds, and flowers per 1,000 pounds of weight. The greatest quantity of the whole plant that was fed, including not only tops but roots, was given to No. 97, which received on July 25 21.2 pounds per 1,000 pounds of weight. No. 91 received 5 pounds on July 2 and 3, and again on July 16 received 21.2 pounds. In none of the cases of feeding *Delphinium menziesii* was there any evidence of toxic effect, although the plant was fed at different stages, part of it before flowering, part after flowering, and even after seed had commenced to form, and attempts were made to find out whether one part of the plant was more poisonous than another.

If it were particularly poisonous it seemed that the feeding in a single day of 21.2 pounds per 1,000 pounds of weight would have produced some effect. It is true, however, that animals upon the range, when hungry, will sometimes eat enormous quantities of a given plant and it seemed necessary to conduct further experiments in order to demonstrate conclusively whether this plant can poison or not. So far as the experiments of 1909 only were concerned, it appeared probable that the plant was not poisonous, or if poisonous at all would do harm only under exceptional circumstances.

EXPERIMENTAL FEEDING OF DELPHINIUM MENZIESII TO CATTLE IN 1910.

In 1910, 14 feeding experiments of *Delphinium menziesii* to cattle were carried on with 11 different animals. Of these experiments 9 produced illness and 3 death. The result of these experiments showed that the failure to produce poisoning in 1909 was not due to a lack of toxicity in the plant but to feeding it in too small quantities. Doubtless similar results would have been produced in 1909 had the experiments been continued for a longer time. Table V gives a summary of the feeding experiments with *Delphinium menziesii* to cattle in 1910.

TABLE III.—Summary of feeding experiments upon cattle with *Delphinium barbeyi*, 1911.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of animal weight.	Location from which plant fed was obtained.
120.....	Pounds, 600	Pounds, 22	June 8-10.....	Leaves and stems.....	Death.....	Physostigmin, pilocarpin, and strychnin.	Death.....	36.7	Near station.
115.....	700	147	June 8-12.....	do.....	Death.....	Physostigmin, pilocarpin, and strychnin.	Death.....	67.1	Do.
115.....	700	49	June 20-22.....	do.....	23 hours.....	Physostigmin, pilocarpin, and strychnin, and whisky.	Recovery.....	81	Do.
92.....	1,050	85	June 21-23.....	do.....	15 minutes.....	Physostigmin, pilocarpin, and strychnin.	Recovery.....	165.7	Do.
631.....	350	58	June 22-28.....	do.....	Sick, but not down.....	do.....	do.....	51.2	Kebler Pass.
632.....	400	20.5	July 7-8.....	do.....	13 minutes.....	Physostigmin, pilocarpin, and strychnin.	Recovery.....	46.6	Do.
633.....	450	21	July 7-11.....	do.....	17 hours.....	Physostigmin, pilocarpin, and strychnin.	do.....	42.9	Do.
631.....	350	15	July 9-11.....	do.....	1 hour, 10 minutes on 1st day, at times on 2d day.....	Physostigmin, pilocarpin, and strychnin, and magnesium sulphate.	Recovery.....	31.7	Do.
635.....	750	26	July 15.....	do.....	30 minutes.....	Physostigmin, pilocarpin, and strychnin.	do.....	40	Do.
644.....	650	26	do.....	do.....	40 minutes.....	Physostigmin, pilocarpin, and strychnin.	do.....	71.6	Do.
634.....	475	34	July 17-18.....	do.....	21 hours.....	Physostigmin, pilocarpin, and strychnin.	do.....	52	Do.
649.....	500	26	do.....	do.....	Constipated, not down.....	do.....	do.....	51.1	Do.
637.....	450	23	July 25.....	Leaves, stems, and flowers.....	30 minutes.....	Physostigmin, pilocarpin, and strychnin.	do.....	40	Do.
646.....	500	20	do.....	do.....	40 minutes.....	Physostigmin, pilocarpin, and strychnin.	do.....	91.1	Do.
638.....	450	41	July 27-28.....	do.....	21 hours.....	Physostigmin, pilocarpin, and strychnin, and magnesium sulphate, and whisky.	do.....	81.1	Do.
647.....	475	38.5	do.....	do.....	Constipated, not down.....	do.....	do.....	90	Do.
640.....	400	36	July 31.....	do.....	Leaves, stems, flowers, and seed.....	do.....	do.....	76.4	Near station.
642.....	550	42	Aug. 1.....	do.....	Leaves, stems, and flowers.....	do.....	do.....	113	Do.
636.....	500	56.5	Aug. 4-5.....	do.....	do.....	do.....	do.....	76.2	Kebler Pass.
638.....	525	40	do.....	do.....	do.....	do.....	do.....		

TABLE IV.—Summary of feeding experiments upon cattle with *Delphinium menziesii*, 1909.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of animal weight.	Location from which plant fed was obtained.
643.....	450	42	Aug. 3.....	Leaves, stems, flowers, and seed.	6½ hours.....	Physostigmin, pilocarpin, and strychnin.	Recovery.....	93.3	Near station.
640.....	400	67	Aug. 8-9.....	Leaves, stems, and flowers.	Constipated, not down.	do.....	do.....	167.5	Kebler Pass.
634.....	475	129	Aug. 11-13.....	Leaves, stems, flowers, and seed.	do.....	do.....	do.....	271.4	Near station.
645.....	650	84	do.....	do.....	do.....	do.....	do.....	129.5	Do.
641.....	450	2 11.5	Aug. 16, collected on July 30.	Leaves, stems, and flowers.	15½ hours.	Physostigmin, pilocarpin, and strychnin.	Recovery.....	25.6	Kebler Pass.
634.....	475	2 11.5	Aug. 24 collected on July 30.	do.....	Constipated, not down.	do.....	do.....	24.2	Do.

¹ About.² Dry weight.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

Pounds.

TABLE V.—Summary of feeding experiments upon cattle with *Delphinium menziesii*, 1910.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of animal weight.	Location from which plant fed was obtained.
108.....	Pounds. 600	34.25	May 25-26.....	Leaves, stems, and roots.	.....	.....	.....	57.1	Near station.
107.....	600	64.5	May 25-27.....	Leaves and stems.	Fell twice.	.....	Recovery.....	107.5	Do.
107.....	600	21	May 28.....	do.....	About 30 minutes.	Physostigmin, pilocarpin, and strychnin.	do.....	35	Do.
84.....	750	78	May 30-June 1.....	Leaves, stems, and flowers.	.....	.....	.....	104	Do.
108.....	600	64.25	June 3-4.....	do.....	Death.....	Barium chlorid, caffeine, and strychnin.	Death.....	107.1	Do.
117.....	900	79.5	June 7-9.....	Leaves, stems, flowers, and seed.	do.....	.....	.....do.....	88.3	Do.
82.....	1,000	116.5	June 11-14.....	Leaves, stems, and flowers.	18 hours.	Physostigmin, pilocarpin, strychnin, and alcohol.	Recovery.....	116.5	Near station, north of Salt Lick, and Pass Creek.
118.....	250	26	June 17-18.....	Leaves, stems, flowers, and seed.	20 minutes.	Physostigmin, pilocarpin, and strychnin.	do.....	104	Pass Creek.
113.....	900	56	June 20-22.....	do.....	2 hours.	do.....	do.....	62.2	Do.
609.....	500	43.75	June 26-27.....	do.....	5 minutes.	do.....	do.....	87.5	Pass Creek and Webber Park.
609.....	500	7.5	June 28.....	Leaves, stems, and flowers.	Sick, but not down.	.....	.....do.....	15	Kebler Pass.
609.....	500	18.75	do.....	Leaves, stems, flowers, and seed.	2 hours and 45 minutes.	Physostigmin, pilocarpin, and strychnin.	do.....	37.5	Pass Creek.
611.....	450	43.5	June 29-30.....	Leaves, stems, and seed.	Death.....	do.....	Death.....	96.7	Do.
614.....	500	46.5	July 2-3.....	Leaves, stems, flowers, and seed.	1 hour and 5 minutes.	.....	Recovery.....	93	Do.

A few of the typical cases will be noticed in detail, as follows:

CASE 117.

Case 117 was fed on flowering tops of *Delphinium menziesii* from June 7 to June 9, receiving, all told, 79.5 pounds, or about one-eleventh of its weight. At 9.25 p. m. June 9, when disturbed, he attempted to walk and fell down, recovering himself with little effort. Other than this there were at this time no symptoms of poisoning. He was observed up to 10.30 p. m. and at that time seemed to be fairly well. On the morning of June 10 he was found dead. He lay upon the left side with his head lower than the rest of the body. Some of the contents of the stomach had flowed from the mouth and nostrils. The heart was in diastole, both sides being filled with blood. The pericardial fluid was slightly bloody and abundant. The external walls of the ventricles showed petechiæ. The lungs were congested. The fluids of the pleural and peritoneal cavities were also slightly bloody. The trachea contained some of the contents of the rumen. The inner wall of the trachea was congested and this condition extended into the bronchi. The inner wall of the first stomach was inflamed beneath the mucous membrane, the inflammation being especially deep at the cardiac end of the stomach. The same condition of the wall beneath the mucous membrane was found in the second stomach at the cardiac end. The inner wall of the fourth stomach was also inflamed at the cardiac end. The duodenum was not inflamed near the stomach but there were deep spots of inflammation near the entrance of the bile duct. More or less congestion was found throughout the ileum, this being so deep in some spots as to show through from the outside of the intestine. The left kidney was congested. The brain was congested, probably due in part to the fact that the head was lower than the body. The immediate cause of death was asphyxiation, resulting, partly at least, from the introduction of the contents of the stomach into the trachea, although it seems probable that this was accompanied by respiratory paralysis.

CASE 82.

Case 82 was an old cow weighing about 1,000 pounds. From June 11 to June 14 she ate 116.5 pounds of *Delphinium menziesii* in flower. It was noticed on the morning of June 14 that she was much constipated. She showed no other symptoms of poisoning until 3.20 p. m. of that day, when she was found down. She was able, however, to get upon her feet, but went down again immediately. At 3.26 she was given hypodermically physostigmin salicylate, $1\frac{1}{2}$ grains; pilocarpin hydrochlorid, 3 grains; and strychnin sul-

fate, 1 grain. At 3.28 the respiration was 22. Figures 1, 2, and 3 of Plate XIII show her attitudes at various times between 3.20 and 3.28. She got upon her feet again at 3.28. At 3.30 she trembled, arched her back, and fell, rising again at 3.33. At 3.35 she fell, but was upon her feet again at 3.36. Respiration at 3.43 was 42. There was considerable salivation at this time. At 3.56 she began stepping about uneasily with her head down, and, trembling violently, she staggered and fell. Plate XIII, figure 4, shows her attitude just before she fell, while figure 5 shows her position after she was down, and figure 6 shows her attitude as she was attempting to get up at 3.59. At 4 o'clock her pulse was 112 and rather weak. At 4.01 the pulse was 94. At 4.25 she defecated, probably as the result of the dose of physostigmin salicylate. At this time she showed considerable intestinal discomfort. She continued lying down, but apparently feeling quite comfortable from evening until night. At 5.45 a. m., June 15, she was found in the ditch in the corral with water flowing about her. She was thoroughly chilled and constantly trembling, and there seemed to be little probability that she would live. Apparently she must have risen upon her feet during the night, fallen into the ditch, and was unable to get out. The water was turned off and she was given alcohol in hot water as a drench. Half an hour later she was given a drench of whisky. Soon after this she attempted to get up, and at about 9 o'clock was on her feet. After getting up she urinated copiously. It seemed probable in this case that defecation produced by the physostigmin resulted in relief from the immediate symptoms of larkspur poisoning, and that the alcohol bridged over a period of weakness, due in part to the chill and in part to the effect of the larkspur poisoning. Without the dose of alcohol she would in all probability have died.

CASE 113

Case 113 was a steer weighing about 900 pounds. Between June 20 and June 22 he received 56 pounds of *Delphinium menziesii* tops, which included flowers and seeds, the full amount being about one-sixteenth of his weight. At 9.30 p. m. June 22 he was found lying in the corral in a normal manner, but when disturbed he was unable to rise. At 9.35 he attempted to get up, fell over on his side, and was unable to raise himself again. He was given, hypodermically, physostigmin salicylate, $1\frac{1}{2}$ grains; pilocarpin hydrochlorid, 3 grains; and strychnin sulphate, 1 grain. The pulse at this time was 72 and rather weak. Respiration was 16 and fairly deep. While down he was making violent attempts to rise, kicking and lifting his head rather high and then falling back. This action seemed to be more pronounced after the remedy was given, and it was a question

whether it was not partly caused by the peristaltic action resulting from physostigmin salicylate. At 10 p. m. the pulse seemed slightly stronger. He was evidently in pain, as he groaned a great deal of the time. At 11.20 it was found that he had moved himself quite a little distance in the corral and passed a small amount of hard feces. At 11.30 he got upon his feet and walked about the corral. His gait, however, was stiff, the stiffness being particularly noticeable in the hind legs. At 11.44 he passed a considerable amount of feces and acted as though he wished to eat. As he appeared to be very much better at this time, he was left for the night, and was found in good condition at 7 a. m. June 23. He was turned into the pasture at 8.30. In the afternoon of this day he was found in a clump of aspens in the pasture and was driven out. He went about 100 yards in a slow trot, going down a side hill, and fell. This was at 3.55. At 4.05 he began to vomit. His pulse was about 85 and weak. At 4.12 respiration had ceased. The pulse was perceptible for about three minutes, stopping at 4.15. The animal was slightly bloated at first and began bloating rapidly when down. A considerable amount of material from the rumen had been vomited. At the autopsy the heart was found in diastole. The outer walls were slightly inflamed. Both ventricles were dilated and full of blood. The veins under the skin were congested. The nares, larynx, and trachea were full of the material vomited from the stomach, and this material had also extended into the bronchi. The walls of the fourth stomach were greatly inflamed, and the walls of the duodenum, jejunum, ileum, and rectum were slightly inflamed. A microscopic examination was made of the contents of the stomach, and it was found that *Delphinium barbeyi* was present. It seems probable that the animal, after recovering from the poisoning by *Delphinium menziesii* had commenced to eat the *Delphinium barbeyi*, which was fairly abundant in the pasture, and that his death was caused by this dose of the tall larkspur.

CASE 609.

Case 609 was a yearling heifer weighing about 500 pounds, loaned to the station for experimental purposes. Feeding was commenced at 7.05 a. m. on June 26, the material being tops of *Delphinium menziesii*, which at this time was mature and included seeds. On June 26 and 27 she ate 43.75 pounds. The material on June 27 contained flowers as well as seed. Distinct symptoms of poisoning were observed early on the morning of June 28. Before that it had been thought that she was somewhat uneasy, but the symptoms were not positive. At 4.55 a. m. she got up and walked a few steps, trembled, and fell, but at 5 she got upon her feet and after this time was able to stand. She was down only about five minutes. During the

day she ate about $7\frac{1}{2}$ pounds of *Delphinium menziesii*. At 4 p. m. she appeared uneasy. There was occasional forcible expiration and much constipation. After a time her uneasiness seemed to subside and she began to ruminate and appeared hungry. At 5 p. m. she was run around the corral, with no result. Feeding was renewed at 5.15 p. m., and during the evening she received 18.75 pounds of *Delphinium menziesii*, including the seeds. At 9.30 p. m. she was found with her back arched, but appeared fairly well. At 10.15 p. m. she stood with her tail between her legs and her head rather low. The impression was that the poison was taking effect. She started to run about the corral, stumbled and partly fell, but recovered herself, then fell and could not rise. The observer went to the laboratory to get a remedy and on returning found her upon her feet, and she remained upon her feet even after running around the corral. She was left again at about 11.40. During all the time she was watched she was uneasy. She occasionally would expel gas rather violently, and once she moaned. She was evidently very uncomfortable, but not very sick. At 12.10 midnight she was on her feet, but moved around the corral slowly. She began to back uneasily with her head low, and fell and, although making violent efforts to rise, was unable to do so. At 12.15 she was given subcutaneously physostigmin salicylate, 1 grain; pilocarpin hydrochlorid, 2 grains; and strychnin sulphate, 1 grain. She was in great pain, breathed noisily, and occasionally expelled gas from her stomach. She would stretch her legs out rigidly and kick violently, moaning all the time. At 12.40 she passed a little hard feces. At 12.45 her respiration was 40 and continued at about that rate. She perspired copiously and acted like an animal in a violent attack of colic. At 1.25 she raised her head, making efforts to rise, but fell back, striking her head violently upon the ground. This was repeated at 1.30. From this time she seemed to be somewhat easier, although the change was rather gradual. She lay upon her side, breathing noisily. Her legs much of the time were stiff, but the movements were not so convulsive and apparently her pain was less. During the most violent spasms of pain she was given a little ammonia inhaled from saturated cotton. At about 2 a. m. after several violent efforts she succeeded in getting upon her feet, staggered across the corral, but did not fall. She was watched at intervals during the rest of the night and was upon her feet all the time. She was given a little hay and corn meal in the morning and hay at noon. On the following day she appeared to be entirely recovered.

EXPERIMENTAL FEEDING OF DELPHINIUM ROBUSTUM TO CATTLE.

The species of larkspur which has been identified as *Delphinium robustum* and which is quite different from *Delphinium barbeyi* and *Delphinium menziesii* of the Mount Carbon station is abundant in

parts of the Cochetopa and Uncompahgre National Forests. It is more nearly related to the *Delphinium barbeyi* than to *Delphinium menziesii*, and should be classed as one of the tall larkspurs. The entire feeding experiment with this plant was carried on at the ranch of A. J. Hack, of Parlins, Colo. Two animals, Nos. 629 and 630, were used for feeding.

The feeding began at 7.15 a. m. on August 22, 1910. No. 630 ate very little of the larkspur and was not affected by it. No. 629, weighing about 500 pounds, ate on August 22 about 20 pounds, which included leaves, stems, flowers, and seeds. No effect was produced, and at 6 a. m. on August 23 she seemed to be all right with the exception of constipation, but at 10.35 she was found down on her side and unable to rise. She struggled when approached, but was unable to raise herself even upon her belly. At 10.40 respiration was 32 and somewhat irregular. There was some trembling of the muscles of the sides and some salivation. At 10.45 the pulse was 80 and weak. At 11.10 respiration was 50, very irregular and shallow. At 11.34 she arose without any marked difficulty, but at 11.37, after being run about, she went down again, trembling before she fell. With assistance she got upon her feet and started to run, but fell again. She was up again at 11.42 and during the rest of the day seemed to be all right. In the evening she was given more of the *Delphinium robustum*, it being estimated that she ate about 8 pounds. On the morning of August 24 she was found down and unable to rise. A little later she arose with some difficulty, but fell, getting upon her feet again at 6.35, when she immediately fell and was unable to rise. At 6.40 she got up and walked away. She started to run and fell, but immediately got upon her feet, only to fall again, trembling as she fell. At 6.45 she got upon her feet and walked about in a normal manner. She was seen frequently during the forenoon and seemed to be all right, with the exception of some constipation.

It will be noticed that the symptoms as recorded are exactly comparable with those found in the cases of poisoning by *Delphinium barbeyi* and *Delphinium menziesii*.

EXPERIMENTAL FEEDING OF DELPHINIUM CUCULLATUM TO CATTLE.

During the summer of 1912, at the Greycliff station, *Delphinium cucullatum* was fed experimentally to six head of cattle with resulting symptoms of poisoning in four, none of the cases resulting fatally. One was only slightly sick and received no remedy. The second was treated with arecoline with no apparent good results, but recovered after treatment with magnesium sulphate, a glycerin enema, and a hypodermic injection of whisky. The others were treated in the routine way worked out at Mount Carbon with physostigmin and pilocarpin and recovered. The symptoms were strictly comparable with those produced by the other species of *Delphinium* and it does not

seem necessary to give the history of the cases in detail. In the discussion later in this paper the minor points of difference will be brought out. Table VI gives the summary of these feeding experiments.

TABLE VI.—*Summary of feeding experiments upon cattle with Delphinium cucullatum.*

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	
	<i>Pounds.</i>	<i>Pounds.</i>	1912.		
650.....	550±	12.5	June 28-29.....	Leaves and stems.	
653.....	700±	18.5	June 30-July 1.....	Do.	
654.....	600±	21	July 23.....	Leaves, stems, and flowers.	
652.....	500±	24.5	August 8-9.....	Leaves, stems, flowers, and seeds.	
653.....	700±	2.5	August 30-31.....	Leaves, stems, and seed.	
651.....	550±	17.5	September 3.....	Do.	

No. of animal.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of animal weight.	Location from which plant fed was obtained.
				<i>Pounds.</i>	
650.....	Slightly sick; not down		Recovery	22.7	Cabin corral.
653.....	18 hours, 40 minutes...	Arecolin, strychnin, magnesium sulphate, glycerin, and whisky.	do.....	26.4	Do.
654.....	4 hours, 15 minutes, first attack; 20 hours, 30 minutes, second attack.	Physostigmin, pilocarpin, strychnin, linseed oil.	do.....	35	Do.
652.....	25 minutes, first attack; 14 hours, second attack.	Physostigmin, pilocarpin, and strychnin.	do.....	49	Do.
653.....				3.5	Do.
651.....				31.8	Do.

POISONING OF HORSES BY LARKSPUR.

Apparently there are no accounts of the poisoning of horses by larkspur. Among the stockmen it is a general belief that horses are not poisoned by this plant and can be grazed with impunity in localities where cattle are certain to suffer from the poison. In some localities in the Sierras where many cattle have been lost within limited areas, the ground has been fenced in and successfully used for pasturing horses. Although the belief is general that horses are not poisoned by larkspur, it does not follow that they can not be. Accordingly the following experiments were undertaken with cases 72 and 78.

CASE 72.

Case 72 was a horse about 4 years old which had been used in previous feeding experiments. During July 9 and 10 he ate 11 pounds of leaves and stems of *Delphinium barbeyi* without any effect. Another experiment was made, commencing on the morning of August 24 and continuing until September 4. During this time he ate 192 pounds, or, on the basis of 1,000 pounds of weight, 274.3 pounds. The feeding was then interrupted on account of storms,

but was resumed on September 9. From this time until September 14 he ate 78.25 pounds of *Delphinium barbeyi*. The material fed in these later experiments was mature and dry. No effect resulted from the larkspur feeding except that part of the time the horse seemed sleepy and lifeless. It should be noted that this feeding was rather late in the season, when, as shown elsewhere, the larkspur is only slightly toxic.

CASE 78.

Case 78 was a horse weighing about 600 pounds, which had already been used at Hugo in the loco experiments. An attempt was made early in July to feed it both *Delphinium barbeyi* and *Delphinium menziesii*, but without any effect. On August 23 it was brought into the corrals in order to try a prolonged feeding experiment with *Delphinium barbeyi*. The material given was collected in Kebler Pass and consisted of tops, including the fruit. The animal was fed from August 24 to September 2, inclusive. During this time it ate 168½ pounds, or, in the ratio of its weight, the quantity eaten was as 1 to 3.6. No effect of the feeding was noticed until September 2. Between 10 and 11 o'clock of the morning of September 2 it was noticed that the action of the hind legs was stiff and that the animal acted as if he did not have complete control of his legs. There was some trembling of the muscles of the flanks and twitching of the muscles of the lips and nostrils. The abdominal muscles contracted as though in pain. In walking he straddled with his hind legs and appeared weak behind. He was constantly moving about, apparently from pain. The back was arched up, and he was very much constipated. At 11.25 he was given some hay and commenced to eat it, but while eating stepped about uneasily as though in pain. At 12.15 he was found down, but was started up and got upon his feet without any difficulty, although his movements after rising were somewhat uncertain. After rising he kept walking about, evidently feeling very uncomfortable. He lay down again at 12.25. His respiration at this time was 78. Figures 1, 2, 3, and 4 of Plate XIV show various attitudes assumed during his illness; figure 1 shows clearly the discomfort under which the animal was laboring; figure 2 shows him after he lay down; figure 3 shows his attitude at 1.08, when he was most severely ill; and figure 4 shows him a little later than this when he was upon his feet but still feeling great discomfort. At 1.55 he was lying down again, and when started and run around the corral he moved readily, showing little tendency to stagger or to fall. At 3 p. m. he was found standing in the corral, his lips no longer trembling, and he no longer had a tendency to walk about uneasily as earlier in the day. His gait was slow, however, and he was sleepy. At this

time evidence of pain was less marked. No further pronounced symptoms appeared during the day of September 2.

On the morning of September 3 he still exhibited some trembling of the muscles of the hind legs and of the flanks and his gait showed the same symptoms of stiffness as seen on the preceding day, but during the day his condition improved. On this day he ate 6 pounds of leaves, stems, and seeds. On the morning of September 4 he appeared to be in good condition. The feeding was resumed, and he ate about 12 pounds of *Delphinium barbeyi*. During the latter part of the forenoon and in the afternoon he again showed distinct symptoms of poisoning. The back was arched much of the time and he straddled in walking. There was distinct evidence of abdominal pain. During much of the time he exhibited trembling in the superficial muscles. Sometimes in lying down he would groan, evidently being in severe pain. Gradually, however, he recovered, and on the morning of September 5 appeared to be again in normal condition.

He was fed again, from September 9 to September 14, receiving fresh material of *Delphinium barbeyi* collected at Kebler Pass. During this time he ate 126.75 pounds. There were no distinct evidences of poisoning from this feeding, although he appeared somewhat dull.

The results of these experiments seemed to prove conclusively that horses can be poisoned with larkspur and that they have the same general symptoms as cattle. Table VII gives the summary of these feeding experiments.

TABLE VII.—Summary of feeding experiments upon horses with *Delphinium barbeyi*, 1909.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.
	<i>Pounds.</i>	<i>Pounds.</i>	1912.	
72.....	700	11	July 9-10.....	Leaves and stems.
78.....	600	168.5	Aug. 24-Sept. 2.....	Leaves, stems, and seed.
72.....	700	192	Aug. 24-Sept. 4.....	Do.
78.....	600	6	Sept. 3.....	Do.
78.....	600	12	Sept. 4.....	Do.
72.....	700	78.25	Sept. 9-14.....	Seed and seed stems.
78.....	600	126.75	do.....	Leaves and stems.

No. of animal.	Time sick until able to stand.	Remedy used.	Result.	Amount fed to 1,000 pounds of animal weight.	Location from which plant fed was obtained.
				<i>Pounds.</i>	
72.....				15.7	Near station.
78.....	Sick, but able to stand.		Recovery...	280.8	Kebler Pass mostly.
72.....				274.3	Do.
78.....	Sick, but able to stand.		Recovery...	10	Kebler Pass.
78.....	do.....		do.....	20	Do.
72.....				111.8	Do.
78.....				211.2	Do.

For our purpose it did not seem necessary to carry on any further experimentation with horses as there is no reason to think that they are ever poisoned upon the range. Observation of horses on the range and in pastures containing larkspurs showed that these animals do not eat the larkspur early in the season. In the fall after the tall larkspur has become dry, horses, like cattle, seem to have a fondness for the larkspur leaves, although they do not eat them so greedily as do the cattle. Inasmuch as the larkspur at this time is not poisonous, no harm results from this feeding.

EXPERIMENTAL FEEDING OF DELPHINIUM BARBEYI TO SHEEP IN 1910.

Five experiments were carried on of feeding *Delphinium barbeyi* to sheep. These experiments were commenced June 3 and continued until July 17. Three of the animals, Nos. 118, 104, and 114, were fed tops of the plant, including the leaves and stems. The other two, Nos. 108 and 116, were fed tops, including the leaves, stems, and flowers. Table VIII gives a summary of these experimental feedings.

Case 118, weighing 97 pounds, was fed 67.75 pounds between June 3 and July 22 without any results. Case 104, weighing 90 pounds, was fed 68 pounds between June 23 and July 5 without any injurious results. Case 114, weighing 65 pounds, received 31.75 pounds between June 23 and July 5 without results. Case 108, weighing 94 pounds, was fed 104 pounds between July 6 and July 17, or 10 pounds more than its own weight, without being poisoned. Case 116, weighing 93 pounds, received 121 pounds between July 6 and July 17, or 28 pounds more than its own weight, without being affected.

Thus of these 5 sheep, eating from 48.8 to 130.1 pounds, on a basis of 100 pounds average weight, none were injuriously affected by the plant.

EXPERIMENTAL FEEDING OF DELPHINIUM BARBEYI TO SHEEP IN 1911.

In 1911 two experiments were made of feeding *Delphinium barbeyi* to sheep. Although the general results of the work of 1910 were conclusive, it seemed best to feed some of the plant at the early stages of its growth in order to make sure that it was not poisonous at that time.

Sheep 134, weighing 140 pounds, was fed from June 19 to June 25, 49 pounds of the leaves and stems of *Delphinium barbeyi* before blossoming. This was at the rate of 35 pounds per 100 pounds of weight of the animal.

Sheep 135, weighing 136 pounds, between the same dates, was fed 37 pounds of the same material, or 27.2 pounds per hundredweight of the animal.

Neither of these sheep showed any effects from the feeding, and inasmuch as the amount fed, relative to the weight of the animal, was

so much larger than that necessary to poison cattle, it was deemed conclusive evidence that the plant at this stage is not poisonous to sheep.

TABLE VIII.—Summary of feeding experiments upon sheep with *Delphinium barbeyi*, 1910 and 1911.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Amount fed to 100 pounds of animal weight.	Location from which plant fed was obtained.
	<i>Pounds.</i>	<i>Pounds.</i>	1910.		<i>Pounds.</i>	
118.....	97	67.75	June 3-22.....	Leaves and stems.....	69.9	Near station.
104.....	90	68	June 23-July 5.....	do.....	75.5	Do.
114.....	65	31.75	do.....	do.....	48.8	Do.
108.....	94	104	July 6-17.....	Leaves, stems, and flowers.....	110.6	Do.
116.....	93	121	do.....	do.....	130.1	Do.
			1911.			
134.....	140	49	June 17-25.....	Leaves and stems.....	35	Do.
135.....	136	37	do.....	do.....	27.2	Do.

EXPERIMENTAL FEEDING OF DELPHINIUM MENZIESII TO SHEEP IN 1910.

Four sheep weighing approximately 100 pounds each were fed various quantities of *Delphinium menziesii*. Table IX gives a summary of these experimental feedings.

Sheep 113 was fed 32.75 pounds of roots, the feeding continuing from June 2 to June 13. On June 13 the available supply of roots for feeding was exhausted and the sheep was given the tops, including leaves and flowers. This feeding was continued through June 22, the animal having received, altogether, 50.25 pounds of this material. Sheep 125 was fed 111.75 pounds of tops, including leaves, stems, and flowers, the feeding continuing from June 2 to June 16. Sheep 119 was fed from June 15 to June 26, the material being the entire top, including leaves, stems, flowers, and seeds. During this time the animal ate 101 pounds, or very nearly its own weight. During the same period, June 15 to June 26, sheep 123 was fed 73.75 pounds of the same material.

The *Delphinium menziesii* fed to sheep 113 during the first experiments of root feeding was collected near the camp. All the rest of the material fed to the sheep was collected at Pass Creek Park and was of fairly mature plants. The feeding of this plant to sheep produced no injurious effect whatever. The animals did not even lose much in weight, and that little could be accounted for by reason of confinement and the fact that they were being fed but a single variety of plant.

It should be added that sheep 160 ate in one day, on the basis of 100 pounds of weight, 5.98 pounds, and sheep 177, 6.9 pounds. In the experiments of 1910 and 1911 sheep 118 ate in one day 6.7 pounds; sheep 114, 6.5 pounds; sheep 135, 7.4 pounds; sheep 134, 7.8 pounds;

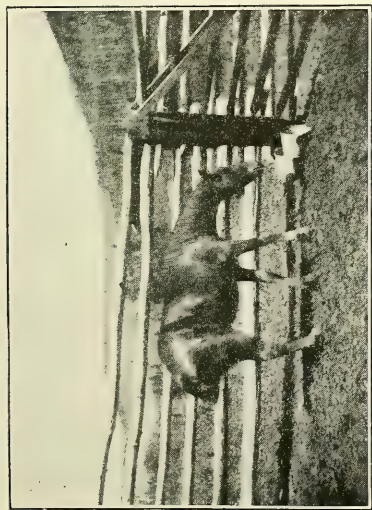


FIG. 1.—CASE 78, SHOWING DISCOMFORT.

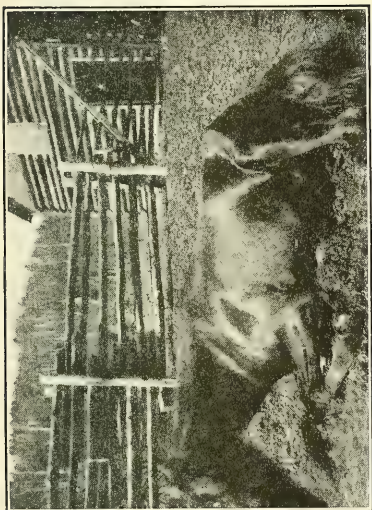


FIG. 2.—CASE 78, LYING DOWN BUT ABLE TO HOLD HIS HEAD ERECT.

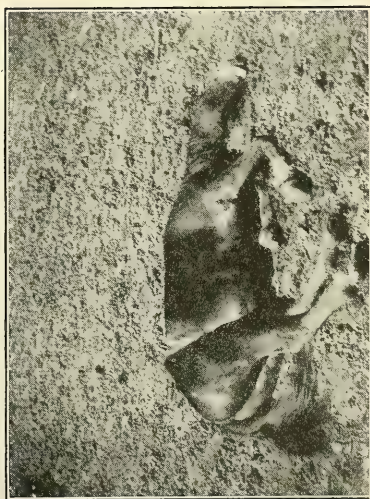


FIG. 3.—CASE 78, WHEN FEELING THE WORST.

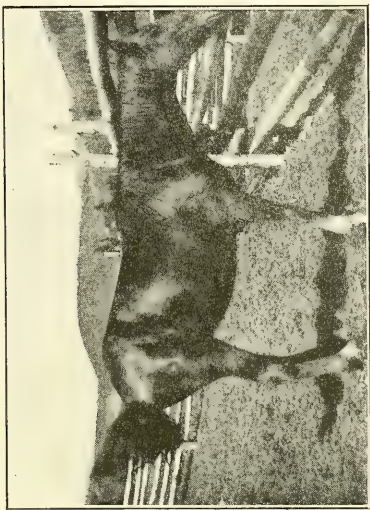


FIG. 4.—CASE 78, A LITTLE LATER THAN FIG. 3, WHEN ABLE TO STAND.



FIG. 1.—SHEEP FEEDING UPON DELPHINIUM MENZIESII.



FIG. 2.—ANOTHER VIEW OF SHEEP FEEDING UPON DELPHINIUM MENZIESII.

sheep 108, 11.7 pounds, and sheep 116, 15.6 pounds. Inasmuch as the toxic dose for cattle, as is shown later, is from 3 per cent and upward of the animal's weight, the sheep ate, relatively to their weight, from 2 to 5 times as much as is necessary to poison cattle without harmful results.

TABLE IX.—Summary of feeding experiments upon sheep with *Delphinium menziesii*, 1910.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Amount fed to 100 pounds of animal weight.	Location from which plant fed was obtained.
	<i>Pounds.</i>	<i>Pounds.</i>			<i>Pounds.</i>	
125.....	100	111.75	June 2-16....	Leaves, stems, and flowers	111.75	Pass Creek.
113.....	100	32.75	June 2-13....	Roots.....	32.75	Near station
113.....	100	50.25	June 13-22....	Leaves, stems, and flowers	50.25	Do.
119.....	106	101	June 15-26....	Leaves, stems, flowers, and seed.	95.3	Pass Creek.
123.....	90	73.75	do.....	Leaves, stems, and flowers	81.9	Do.

EXPERIMENTAL HERDING OF SHEEP UPON DELPHINIUM MENZIESII.

Delphinium menziesii was particularly abundant in Pass Creek Park, near the Mount Carbon Station. When the plant was in blossom the whole park seemed to be colored purple. Plate XV, figures 1 and 2, show sheep feeding and give a good idea of the abundance of the plant in the park. It was thought desirable to try an experiment of close herding a bunch of sheep upon the larkspur. If *Delphinium menziesii* would poison sheep upon the range, symptoms ought to be developed by such close herding, for if they ate freely it would be evident that a much larger quantity would be eaten than under any ordinary circumstances that would prevail in range feeding. Accordingly, on June 14, 19 sheep were taken from the station to Pass Creek Park and were kept until the afternoon of June 17. During the day they were herded upon the larkspur area, and corralled at night in an old cabin. Most of them ate very freely of the *Delphinium menziesii*. Notes taken in regard to the individual sheep show that five may be considered to have eaten only a little. All the rest, however, ate a considerable quantity. They were not allowed to stray from the larkspur patch, and the feeding while they were herded resulted in clearing swaths running through the larkspur area where most of the plants had been eaten. During this time they ate very freely, apparently relishing the taste of the larkspur. Plate XV, figures 1 and 2, which were snapshots taken during the feeding, show how readily they took to the plant. The sheep were watched very closely for possible symptoms of larkspur poisoning. No such symptoms, however, developed. All were brought back to the camp on June 17 not only none the worse for their ex-

perience but apparently, if anything, benefited by the opportunity of free pasturing. During the summer the band of sheep was corralled nights in a small pasture which during the month of June was almost entirely covered with *Delphinium menziesii*. All of this plant was eaten out with the other plants growing in the pasture and no injurious effect was produced upon any of the sheep.

These experiments, in conjunction with the corral feeding experiments, seemed to the station force to prove conclusively that sheep can eat *Delphinium barbeyi* and *Delphinium menziesii* with impunity, and that no fear of poisoning need be entertained from pasturing sheep on a range containing these plants.

EXPERIMENTAL FEEDING OF DELPHINIUM ANDERSONII TO SHEEP IN 1911.

Inasmuch as the belief is very common among the sheepmen of California and Oregon that sheep are poisoned by eating the roots of *Delphinium andersonii*, two experiments were made of feeding the roots of this plant. The material was collected at McDowell's Creek, near Lakeview, Oreg., on June 24, 1911, and forwarded to the station at Mount Carbon. As it is somewhat difficult to make sheep eat the roots of the plant, and as the quantity was limited, it was decided to administer the material in the form of a drench. The roots after being washed were ground fine and mixed with enough water to permit of their administration. Two animals were used.

Sheep 155, weighing 131 pounds, was brought in for experiment on August 9. At 11.30 a. m. on August 11 it was given 200 grams of dried roots and on August 12 at 11 a. m. and 2.30 p. m. it was given the same amount. It thus received 1.3 pounds of the roots. Inasmuch as these had been air dried it would be equivalent to at least twice that amount of fresh roots.

Sheep 136, weighing 153 pounds, was brought in for feeding on August 13. At 10.30 a. m. on August 14 it was given 200 grams of the roots. The same quantity was administered at 2.20 p. m., 4.45 p. m., and 7.45 p. m., and 150 grams were given at 9.45 p. m. Thus, this animal received between 10.30 a. m. and 9.45 p. m. 2.1 pounds of dried roots. This would be equivalent to at least 4.2 pounds of fresh material. It is highly improbable that the sheep upon the range, grazing upon larkspur, would obtain anything like this amount of larkspur roots, so that this experiment in conjunction with the experimental work of feeding roots of other larkspurs at Mount Carbon seems to be fairly conclusive that sheep are not poisoned by eating roots of *Delphinium andersonii*. Table X gives the results of this experimental feeding.

TABLE X.—Summary of feeding experiments upon sheep with *Delphinium andersonii*, 1911.

No. of animal.	Weight of animal—		Amount of plant fed.	Date of feeding.	Part of plant fed.	Amount fed to 100 pounds of animal weight.	Location from which plant fed was obtained.
	Before.	After.					
155.....	Pounds 131	Pounds. 126	Pounds. 1 1/3	1911. Aug. 11-12	Roots..	Pounds. 1	McDowells Creek, Oreg. Do.
136.....	153	149	1 2/1	Aug. 14	...do...	1.4	

¹ Dry weight.

EXPERIMENTAL FEEDING OF DELPHINIUM BICOLOR TO SHEEP IN 1912.

The preceding experiments of feeding *Delphinium barbeyi*, *D. menziesii*, and *D. andersonii* with negative results rendered it extremely probable that none of the species of larkspurs are poisonous to sheep. It was assumed that probably *Delphinium bicolor*, the Montana low larkspur, would be harmless. In the summer of 1912 two sheep were fed upon this plant, Table XI, giving the details. No symptoms of poisoning occurred in either case, although they received much more than it is at all probable they could obtain when grazing.

TABLE XI.—Summary of feeding experiments upon sheep with *Delphinium bicolor*, 1912.

No. of animal.	Weight of animal.	Amount of plant fed.	Date of feeding.	Part of plant fed.	Amount fed to 100 pounds of animal weight.	Location from which plant fed was obtained.
160.....	Pounds. 92	Pounds. 23.5	June 23-July 2	Leaves, stems, fruit, and some flowers.	Pounds. 25.54	Geo. Hughes's.
177.....	51-48	16.5	July 5-12.....	Leaves, stems, and fruit....	32.35	Do.

PART III.—RESULTS AND CONCLUSIONS.

ANIMALS AFFECTED BY LARKSPUR POISONING.

Cattle.—The experimental work resulted in the confirmation of the general opinion of the poisonous effect of the larkspurs upon cattle.

Horses.—Horses may be poisoned by larkspur, but they do not voluntarily eat enough of the plants to harm them. They eat more or less of it when grazing, but there is no evidence that they are ever poisoned by it under ordinary range conditions.

Sheep.—As the result of the feeding experiments with *Delphinium barbeyi* and *Delphinium menziesii* at the Mount Carbon station, the definite conclusion was reached that these two plants do not have

any poisonous effect upon sheep. Not only were no poisonous effects produced by close feeding upon the plant but the animals did not lose weight and seemed to thrive upon larkspur as a fodder. Inquiry among the stockmen of the Gunnison and neighboring stock ranges brought out the fact that there is a general belief among them that larkspur is never poisonous to sheep. Sheep have been grazed upon the range not many miles from the Mount Carbon station for many years and there are no records of losses from larkspur poisoning. Inasmuch as the feeding of *Delphinium andersonii* and *Delphinium bicolor* was also without result it seems probable that all species of larkspur are harmless so far as sheep are concerned. These results are in harmony with those reached by S. B. Nelson, in Washington, but apparently distinctly contradict the work of Wilcox, in Montana (1897).

A careful examination of Wilcox's original paper shows that the evidence in regard to larkspur poisoning in Montana is hardly conclusive. He finds that a certain number of sheep died and that these animals had been eating larkspur, but it does not follow, of course, that larkspur was the cause of the fatal results, and, with the exception of giving extracts to three lambs, no experimental evidence of larkspur poisoning is adduced. It may be considered possible that the symptoms noted from the extracts might be explained in other ways. It should be noted, however, that the detailed symptoms of larkspur poisoning of sheep, as given by Dr. Wilcox, correspond very closely with the symptoms as given by other authors and with those noted at the Mount Carbon station.

A visit was made to the locality in Montana where this sheep poisoning had taken place, and conversation with the owners of the sheep showed that not only were they very skeptical in regard to the alleged fact that larkspur is the cause of the death of the sheep, as described by Dr. Wilcox, but also that they and other sheepmen of the neighborhood did not consider the larkspurs poisonous to sheep. The results of the work at Mount Carbon and at Greycliff seem to indicate that, in all probability, larkspurs need not be feared by sheep owners. In California and Oregon there is among the sheepmen a belief, widespread and persistently adhered to, that many sheep are lost in the spring from eating larkspur roots. This belief applies, apparently, to *Delphinium andersonii*. This species has a stout stem and grows in a loose soil, so that grazing animals can pull up the roots. It seemed possible that sheep might be poisoned in this way in California and Oregon, even if they were not harmed in Colorado. The experimental feeding of the roots of *Delphinium andersonii* (p. 58), taken with the other results of feeding sheep, makes it probable that the sheepmen are mistaken in

their idea that the roots of *Delphinium andersonii* are poisonous to sheep.

The somewhat suprising result of the feeding work upon larkspur, showing that of two animals so similar in their physical organization as cattle and sheep one is poisoned and the other not affected has, of course, some physiological explanation. Just what this is has not been determined experimentally. It has been shown, however, that sheep excrete the alkaloid in their urine, and it may be, perhaps, assumed that they excrete with sufficient rapidity to remove the poisonous principle before toxic symptoms appear. It should be noted in this connection that there is still a possibility that the alkaloid might be given experimentally in a quantity so great that the excreting powers of the sheep would be unable to remove it in time to prevent intoxication. It is intended later to complete this experimental study. The experiments do show conclusively, however, that quantities, relatively to the size of the animals, several times as great as those necessary to poison cattle do not affect sheep, and that sheep on the range are for all practical purposes immune to larkspur poisoning.

If it is true, as we think it is, that sheep can feed upon the larkspur, not only with impunity, but with actual benefit to themselves, it would appear possible that on ranges where heavy losses of cattle have taken place because of larkspur poisoning sheep can graze with no loss. The question may be raised whether certain ranges could not be profitably changed from cattle ranges to sheep ranges on this account or whether it might not be possible, inasmuch as the losses of cattle from larkspur poisoning are largely confined to the earlier part of the season, to graze sheep upon the range during the early part of June or until they had eaten off the low larkspur and then admit cattle.

RECORDED SYMPTOMS OF LARKSPUR POISONING.

Hahn, in his general article on Delphinium in the Dictionnaire Encyclopédique des Sciences Médicales, quotes Orfila. He states that the symptoms of poisoning by Delphinium are nausea, vertigo, weakness, and convulsions, followed by death. Falck and Rörig, 1852, state the symptoms as nausea, salivation, restlessness, convulsions, and death produced by asphyxia and paralysis of the heart. The symptoms as quoted by these two authors may be considered as typical of those reported by investigators of the European Delphiniums.

Macgregor, in 1908, in telling of the symptoms of poisoning in a horse says that it became dull, its pulse was weak, and there was excessive salivation and deglutition, with attempts at vomiting.

Knowles, in 1897, in detailing the symptoms, says that the animals stray about, become dull, and when started go on a straight line until an obstacle is met, then fall. They rarely bloat. There is a dribbling of saliva and a champing of the jaws. Wilcox, in 1897, states that the symptoms of larkspur poisoning resemble those of aconite poisoning. The first signs are a general stiffness and a straddling, noted especially in the hind legs. The stiffness becomes more pronounced until walking is very difficult and evidently painful. Soon there are manifested involuntary twitchings of the muscles of the legs and sides of the body. There is a loss of control and coordination of the muscles. Ordinarily there is no increase in the quantity of the saliva, no champing of the jaws or attempts at swallowing. At first the pulse is less frequent and the respiratory movements are lessened, while the temperature is lowered. Toward the last the respiration is very rapid. The air in the lungs is not renewed and the animal dies of asphyxia or suffocation. In the latter cases the involuntary movements become more frequent and more severe. All four legs tremble and shake violently. The muscles of the body contract spasmodically until the animal totters over and dies in violent spasms.

In Chesnut and Wilcox, 1901, the symptoms are stated practically like those already detailed by Wilcox. They say that the animal generally falls and gets on its feet a number of times, while the muscles of the sides and legs quiver spasmodically. This quivering of the muscles is considered a very characteristic symptom. There is a slight increase in the quantity of saliva and the animal dies in violent convulsions. The symptoms of poisoning from the low and the tall larkspurs are practically the same.

In comparing the symptoms as detailed by these authors it is noticed that there is a good measure of general agreement, and we can say that the characteristic symptoms of Delphinium poisoning are nausea, weakness, excessive salivation, twitching of the muscles of the sides and legs, and convulsions.

It may be added that the reports of the symptoms of larkspur poisoning as given by stockmen all through the region where larkspur is abundant agree very well with those detailed above by these authors. It is said by many of the stockmen that when a poisoned animal is started suddenly it runs a short distance, then falls; it may pick itself up and run a little farther, but eventually it falls and dies. Some of them state that poisoned animals froth at the mouth, and most of them agree that the animals die in spasms.

SYMPTOMS OF LARKSPUR POISONING OBSERVED IN THE EXPERIMENTAL WORK.

In the animals fed experimentally in the corrals the first indication of the poisonous effect of larkspur was that they no longer cared to

eat, and became uneasy, stepping about as though uncomfortable. As the animal walks about the corral the gait becomes "stiff" and the hind legs are ordinarily spread somewhat widely apart, as though it were bracing itself against falling. It walks uncertainly, staggering more or less. If the poison is sufficient in quantity, after moving a short distance the animal falls. In falling it ordinarily goes down very suddenly, the legs sometimes appearing to crumple up. The forelegs give out first, and the animal goes down, frequently with the head extended and the chin lying upon the ground; then goes completely down. In the less acute cases the animal goes down and lies with the head erect. If the case is acute, it will fall over upon its side, lying flat upon the ground, sometimes moving the head up and down.

If frightened in this position, the animal may kick violently. Usually it is impossible for it to get upon its feet again immediately after falling, and after making two or three more or less violent attempts it gives up absolutely. In a short time it will usually get up and may move about. Soon it commences to step about uneasily, ordinarily backing, the back arches up, the head is held low, it trembles, and, after one or more attempts to save itself from falling, goes down as before. This may be repeated a considerable number of times. The pictures show quite well the attitudes assumed by the animals under these circumstances.

When the poisoning has a fatal result the animal may lie for some time with labored breathing before it dies. If it recovers, as the effect of the poison passes off it stands upon its feet longer each time after falling, and eventually walks off, very much as if nothing were the matter. In cases of mild poisoning it sometimes happens that the animal falls, and when it gets upon its feet walks off apparently perfectly well. If under such circumstances it is hurried, it will go down again, with the same symptoms as before.

On the range commonly the first symptom noted is the falling of the animal; it goes down suddenly and generally is unable to rise immediately. Sometimes, if cattle which are apparently all right are driven hurriedly for a few minutes, individuals will fall. The same thing was noticed in the experimental animals; some that had shown no preceding symptoms would suddenly fall after being run about the corral.

The symptoms of poisoning from *Delphinium barbeyi*, *D. menziesii*, *D. robustum*, *D. bicolor*, and *D. cucullatum* were so nearly identical that they could not be distinguished. The time of complete prostration, by which is meant the time during which an animal is unable to continue standing upon its feet, varies in accordance with the acuteness of the attack. In the cases in 1909, which were all of

Delphinium barbeyi poisoning, the average time of the animals experimented upon was 3 hours and 25 minutes; the shortest time was a half hour, and the longest 13 hours. Of the animals poisoned by *Delphinium barbeyi* in 1910 the shortest was 16 minutes and the longest 15 hours and 16 minutes. The average of the 17 cases observed was 2 hours and 7 minutes. In 1911 there were 11 cases of animals made sick by *Delphinium barbeyi*. Of these the shortest period was 13 minutes and the longest 23 hours, with an average of 9 hours and 38 minutes.

Of 6 cases of *Delphinium menziesii* in 1910 the shortest period was 5 minutes and the longest period 2 hours and 45 minutes, with an average of 1 hour and 7 minutes.

In the single case of *Delphinium robustum* which was observed in the Cochetopa Forest, the animal was down during its first attack for 1 hour and 7 minutes, and during the second attack on the succeeding day it was down 40 minutes.

In the case of cattle poisoned by *Delphinium cucullatum* at Grey-cliff, one was not down at all, and, of the others, one was down 18 hours and 40 minutes, while each of the remaining two had two attacks, the second in both cases being very prolonged. No. 654 was down in the second attack 20 hours and 30 minutes.

In almost all cases the evidence was clear that the animals were nauseated. They frequently moved the head back and forth, sometimes shaking it from side to side, these movements clearly indicating a condition of nausea. As the sick animals lay upon the ground, there was often belching of gas at frequent intervals, caused by this condition of nausea. In the cases where vomiting actually took place, the animals were almost sure to die. Of all the experimental animals observed at Mount Carbon, only one that vomited survived. In all the animals that vomited and died, more or less of the contents of the rumen were found in the trachea and bronchial tubes.

The movements of the head also indicated in most cases more or less abdominal pain. Frequently this pain was evidently very severe. The animals were always constipated, sometimes severely so, and without doubt this constipation was connected with the abdominal pain.

Temperatures were taken in a considerable number of cases, both in 1909 and in 1910. These temperatures varied from 101.2° to 102.6° F. There is evidence from this that temperatures, so far as observed, were practically normal. It has been stated by some authors that the temperature at the beginning of the attack is lower. From the observations of the Mount Carbon experimental animals there was no reason to think that larkspur poisoning caused any change whatever in the temperature.

The rate of respiration was noted in a large number of the cases in both years. In general it ran very high. The highest noted was 123, in the case of No. 604, a yearling heifer. Generally speaking, however, it did not go above 60 to 70. In the case of No. 604, the respiration was noted at various periods between 3.15 and 4.22 p. m., the rates observed being 100, 123, 103, 58, 60. In the case of No. 610, in 1910, between 11.45 a. m. and 6.40 p. m., the numbers indicating the rapidity of respiration were 80, 60, 60, 85, 44, 40, 28, 24. These two cases may be considered as typical of the general course of respiration in cases of poisoning. Generally speaking, the respiration was highest and shallow at the most acute stage of the attack and gradually diminished and became deeper as the effects of the poisoning passed off. In nearly all cases, however, even if the animal had apparently entirely recovered, the rate of respiration was still quite high.

The pulse also was noted in a considerable number of cases, and this, as would be expected, was also rapid. The highest observed was 150 in the case of No. 618. Generally speaking, in the acute cases, the pulse ran well toward 100 and was very weak and, as the effect of the poison passed off, would progressively become slower and stronger. In some few cases the pulse during the stage of poisoning was rather low, as, for example, in case of No. 113 in 1909, where the pulse was 50. It immediately, however, went up to 74.

Salivation was not present in all cases, but it was noted in a number of the sick animals. Of the 22 cases sick at the station from eating *Delphinium barbeyi* in 1910, 9 showed more or less marked salivation. It was not a universal symptom but was a common one. Of course, the administration of the remedy physostigmin and pilocarpin increased the salivation, but this symptom was noted before the administration of the remedy, and in cases where no remedy was given.

It is stated by some authors that in larkspur poisoning there is a loss of control of the muscles and that the animals die in violent spasms. This was hardly true of the experimental animals at Mount Carbon. There were involuntary contractions of many of the muscles of the body. These contractions were particularly pronounced in some cases in the muscles around the mouth and nose, which contracted so as to produce a condition of continuous movement of the muzzle. In one or two cases this movement extended to the mandible. The muscles of the shoulders, flanks, and hips contracted spasmodically, and sometimes there appeared to be a muscular trembling over the whole surface of the body. This trembling was much more marked when the animals were standing than when they were down. When down, some of the animals kicked about to some extent, but there

did not appear to be a lack of coordination, and the movements of the animals, while perhaps they might be described as convulsive, could hardly be considered as the movements of violent spasms or convulsions. When the animals attempted to rise, the difficulty, apparently, was weakness rather than a lack of coordination of the muscles, and the kicking of the animals appeared to be due to voluntary attempts to rise rather than to involuntary and spasmodic contractions of the muscles of the legs. It did not seem to the observers that the animals could be said to have convulsions or spasms.

Bloating occurred in some of the cases, but was not a common symptom. In the cases where it was noticed, it seemed to come as one of the later results of the poison. The bloating doubtless adds much discomfort to the animal, and if it lies with the head lower than the rest of the body, may cause death. It is a matter of common knowledge that when animals die of larkspur poisoning upon the range they bloat very quickly, and it seems probable that death may in some cases be immediately caused by the mechanical effects of the bloating.

Recovery from larkspur poisoning is ordinarily very rapid. The animal, after becoming well enough to rise, soon walks away, in a short time begins to eat, and after two or three days shows no effects of the poisoning. Some stockmen believe that cattle do not thrive after being poisoned by larkspur, but from the experimental work it appeared that no permanent injury was caused. Several of the animals were fed upon the larkspur repeatedly in the same season with no bad results in their condition, except the loss of flesh during the days when the experiments were being carried on. In these experiments of using animals repeatedly they were poisoned as readily the second and third times as the first, or, in other words, there is no evidence from the experimental work of acquired toleration; on the other hand, they were no more susceptible to the effects of the poison because of the repeated feedings.

THE TOXIC DOSE OF LARKSPUR.

It was important for practical purposes to determine how much larkspur was necessary to produce poisonous effects. The work of the first season alone did not give very definite indications of the quantity of larkspur necessary to produce poisoning, but taken in conjunction with the work of the succeeding seasons, seems to give results that are quite exact.

From the accompanying charts (see figs. 6 to 12) one can see the toxic dose of larkspur, this being reduced to a uniform scale for animals weighing 1,000 pounds. They show the quantities of larkspur necessary to produce the poisoning, the dates of the experiments, and the length of time during which the plant was fed. The

figures indicate the number of the animal in each case. The letter *S* indicates that the animal was fed seeds, and the letter *L* that leaves were used.

At first glance these charts do not seem to be very instructive. It will be seen that the quantities of *Delphinium barbeyi* necessary to

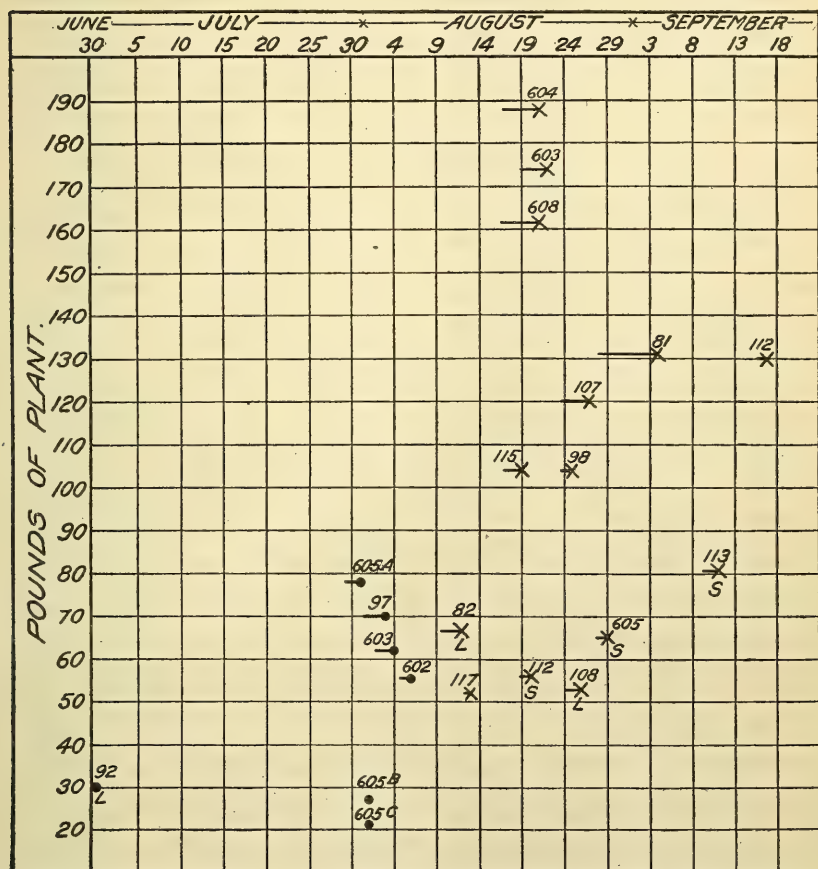


FIG. 6.—Chart of feeding of *Delphinium barbeyi* to cattle experimentally poisoned in 1909, showing dates, quantities fed, and duration of feeding. ● indicates plant collected near station; X indicates plant collected at Kebler Pass about 1,000 feet higher than the station; those marked *L* received leaves and stems; those marked *S* received seeds and the pods and stems bearing them; all the others received the whole top of the plant. The short horizontal line indicates duration of feeding. The weights of plant are given per thousand pounds of animal.

produce poisoning in 1909 varied from 30 pounds in the case of No. 92 to 188 in the case of No. 604. In 1910 the quantities varied from 30.4 pounds in the case of No. 98 to 280.8 pounds in the case of No. 625, while with the *Delphinium menziesii* the quantities varied from 62.2 pounds in the case of No. 113 to 116.5 pounds in the case of No. 82. In 1911 only *Delphinium barbeyi* was fed and the quantity necessary to produce poisoning varied from 34.7 pounds in the case

of No. 635 to 93.3 pounds in the case of No. 643. The averages of these cases, however, are very striking. The cases of 1909 averaged

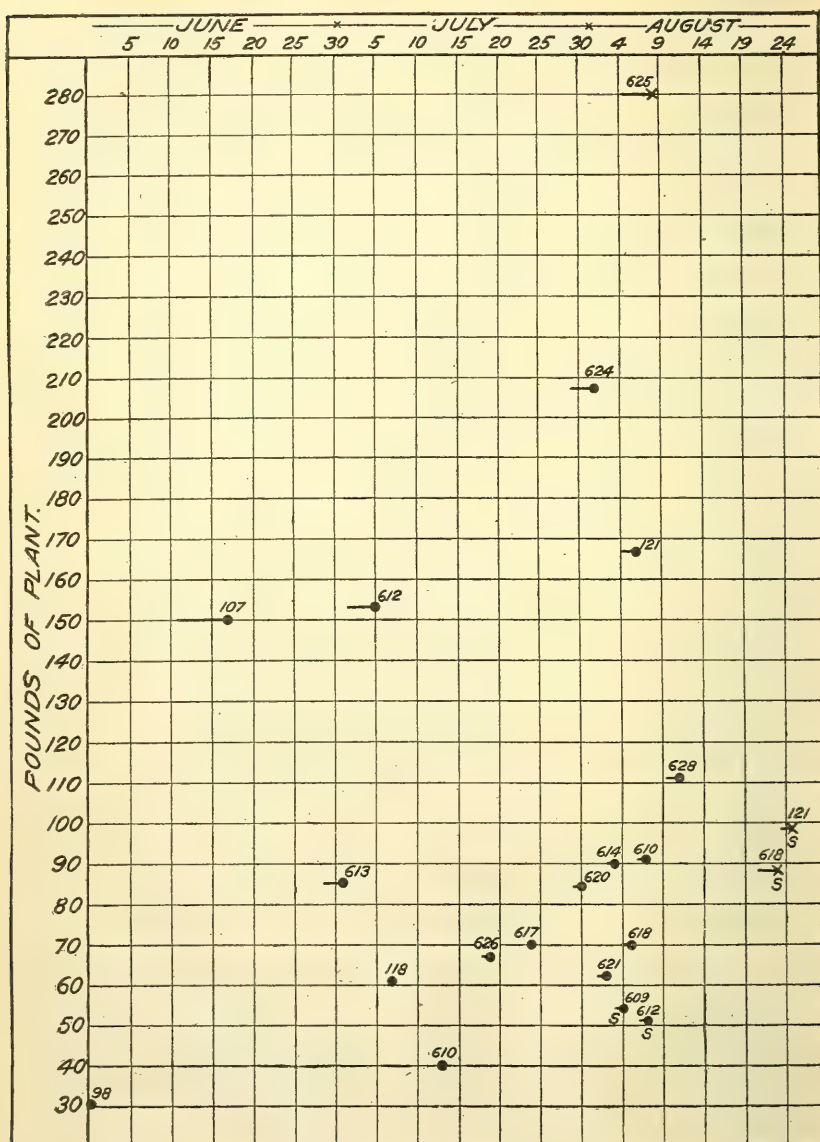


FIG. 7.—Chart of feeding of *Delphinium barbeyi* to cattle experimentally poisoned in 1910, showing dates, quantities fed, and duration of feeding. ● indicates plant collected near station; × indicates plant collected at Kebler Pass about 1,000 feet higher than the station; those marked L received leaves and stems; those marked S received seeds and the pods and stems bearing them; all the others received the whole top of the plant. The short horizontal line indicates duration of feeding. The weights of plant are given per thousand pounds of animal.

92 pounds; the *Delphinium barbeyi* cases of 1910 averaged 100.4 pounds, while the *Delphinium menziesii* feeding of 1910 averaged

95.8 pounds. The cases of 1911, all being of *Delphinium barbeyi* poisoning, averaged 63.3 pounds.

It was the impression among the observers at the station during the first two seasons that about one-tenth the weight of the animal was the toxic dose, and it is certainly rather remarkable that the averages come so close to that quantity. A careful study of the cases of the three seasons, however, shows not only that in the average case this is an over-estimate, but that there are two factors which profoundly modify the quantity necessary to produce poisoning in individual cases. One factor, the seasonal variation in the toxicity of the plants, is discussed under a special heading on page 75. The second factor is the length of time during which the plant was fed. This is indicated in charts 11 to 14, and it will be noted that in general the size of the

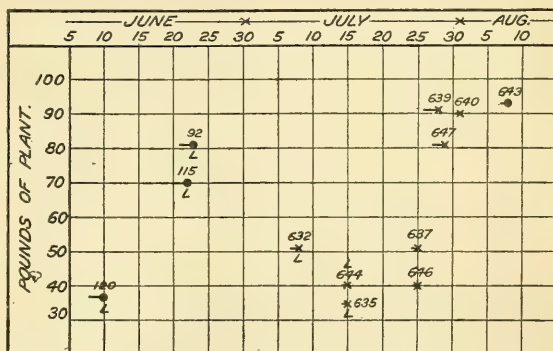
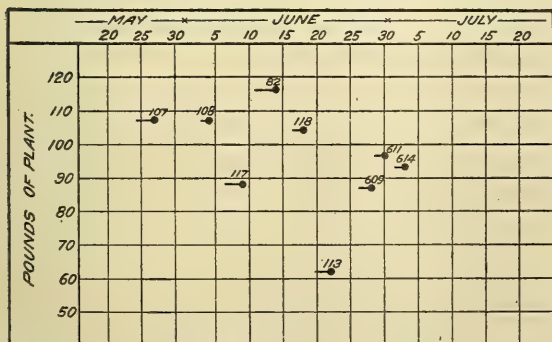


FIG. 8.—Chart of feeding *Delphinium barbeyi* to cattle experimentally poisoned in 1911, showing the dates, quantities fed, and duration of feeding. ● indicates plants collected near station; × indicates plants collected at Kebler Pass about 1,000 feet higher than the station; those marked L received leaves; the others were fed the whole top of the plant.



toxicity plays a more important part in those years. The average toxic dose for 1 day's feeding in 1910 was 54.9 pounds, and in 1911 it was 69.5 pounds. It thus appears that, in the general average of

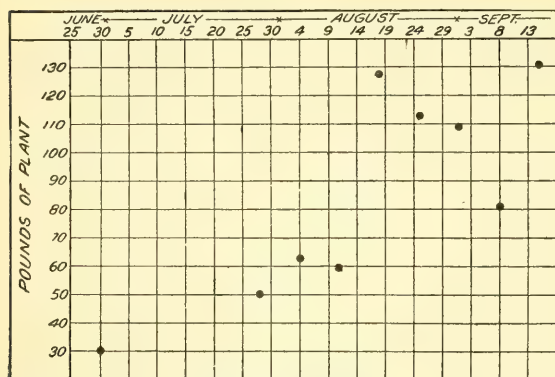


FIG. 10.—Chart of feeding of *Delphinium barbeyi* to cattle experimentally poisoned in 1909 based on weekly averages. The weights of plant are given per thousand pounds of animal.

3, or 4 days shows that few exceeded the toxic limit; of 15 cases in 1909, No. 115 ate 37 pounds, No. 98 ate 58.16 pounds, and No. 112 ate 56.5 pounds. Of 15 cases in 1910, No. 612 ate 43 pounds, No. 610 ate 36 pounds, and No. 121 ate 38 pounds, while in 1911, of 6 cases, No. 639 ate 62.2 pounds and No. 647 ate 46 pounds. It will be noticed that only one of these exceeded the average quantity which poisons in 1 day's feeding, but that all exceeded the minimum.

While some of the differences in the toxic dose can be explained by seasonal differences in the plants and the duration of feeding, many remained unexplained. These differences, under apparently the same conditions, are shown in cases 637, 646, 639, 647, and 640 of 1911. All these animals were fed between July 25 and July 31, with the following

cases, cattle weighing 1,000 pounds will be poisoned if they eat as much as 60 pounds in one day. This quantity varies, however, within wide limits, in one case being as low as 30 pounds, and at the other extreme as high as 93.3 pounds.

A tabulation of the quantities eaten the first day by animals poisoned in 2,

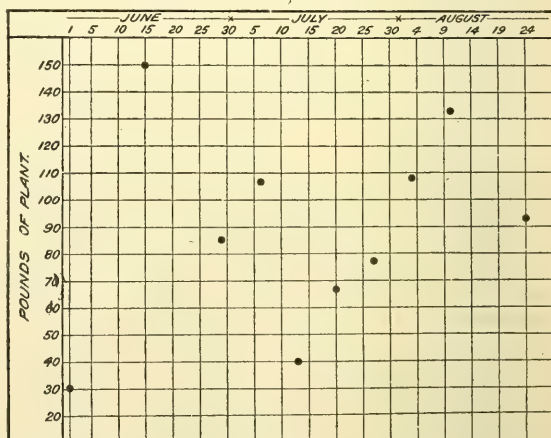


FIG. 11.—Chart of feeding of *Delphinium barbeyi* to cattle experimentally poisoned in 1910 based on weekly averages. The weights of plant are given per thousand pounds of animal.

results: No. 637 was poisoned in 1 day by 51 pounds per 1,000 pounds of weight; No. 646, by 40 pounds; No. 640, by 90 pounds; No. 639 was poisoned in 2 days by 91.1 pounds; and No. 647, by 81.1 pounds. These differences are made more striking when we find that No. 639 ate 62.2 pounds the first day, and No. 647 ate 46 pounds. All these animals were of approximately the same age, treated in the same way with larkspur gathered from the same place, and all were fed within 6 days. The difference may be due in part to the condition of the animals when receiving the plant, for it is reasonable to assume that the rapidity of absorption may be affected by the condition of the alimentary canal and its contents. The condition of the excreting glands, too, may profoundly modify the toxic effect of the plants. Other minor factors doubtless come into play, which may be grouped together under the general term "the varying susceptibility of the individual."

In this connection it may be noted that apparently rumination did not necessarily precede intoxication. While complete notes were not kept on this subject, it was definitely known that some of the animals which

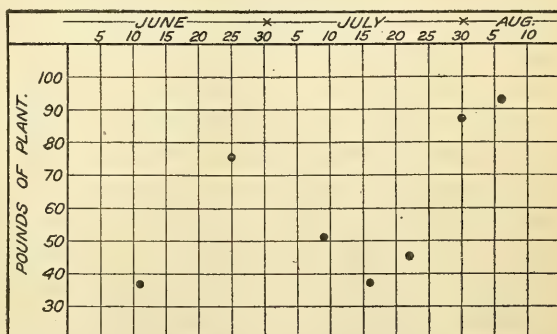


FIG. 12.—Chart of feeding *Delphinium barbeyi* to cattle experimentally poisoned in 1911, based on weekly averages. The weights of plant are given per thousand pounds of animal.

were poisoned in a short time did not ruminate at all. The minimum toxic dose, then, is about 30 pounds, and the average of the three seasons about 84 pounds, with a maximum of 280 pounds. This maximum, of course, would run to infinity late in the season. In the practical handling of cattle it is dangerous for an animal to eat more than 3 per cent of its weight in one day, although it may eat two or three times as much before showing signs of intoxication.

The figures, as given above, in regard to the toxic dose apply to *Delphinium barbeyi* and *Delphinium menziesii*, and it is interesting also to note that the quantity necessary to produce poisoning in the case of *Delphinium menziesii* does not differ materially from the quantity in the case of *Delphinium barbeyi*. In the single experiment with *Delphinium robustum* 40 pounds per 1,000 pounds of weight of the animal produced poisonous effects. Inasmuch as this feeding was rather late in the season, this single experiment would indicate that *Delphinium robustum* might be rather more poisonous than the two species experimented with at Mount Carbon. It is

not safe, however, to draw any definite inference in regard to this. The toxic dose in the experiments with *Delphinium cucullatum* varied from 22.7 pounds to 49 pounds. This apparently indicates a greater toxicity for this species than for the Colorado larkspurs. The experiments were few in number, however, and all taken during the time of probable maximum toxicity of the plant, and it seems likely that a wider experience would show greater conformity to the standard of the Colorado plants.

It is somewhat surprising to notice how great a quantity of larkspur must be eaten in most cases before poisonous effects are produced, and this fact may perhaps be the explanation of the cases which are frequently recorded of the passing of succeeding herds of animals over the same poisonous area, some being poisoned and others going without any harm whatever. It seems very probable that the animals showing the symptoms of poisoning may have come to these areas when particularly hungry and that individuals on this account may have eaten large quantities of the poisonous weed. It is well known that a ruminant when very hungry will eat enormous amounts of material which attracts it. It is also well known that under these conditions animals are more apt to take the plants which are most prominent, and if the larkspurs were more conspicuous than other forage plants it is very probable that the animal under such conditions would eat an unusual quantity and consequently suffer. The practical inference from this is that in handling cattle care should be taken not to drive them over a supposed poisonous area when they are particularly hungry. On this account it would doubtless be better to make the drive over such an area in the afternoon rather than in the morning. It will be noted, too, that the quantity which may be poisonous varies within very wide limits, and that an animal may suffer from eating not more than 25 or 30 pounds. Perhaps special emphasis should be placed upon the fact that the toxic dose is quite large. The larkspurs are not violently poisonous plants and may be eaten in quite large quantities with no bad results. Because a region contains some larkspurs it is not necessarily a dangerous locality for grazing. The region is dangerous only when the plants are present in considerable numbers or when there is a lack of other forage so that the cattle eat the larkspur in large quantities. *Delphinium menziesii* in some localities is so scattered that it can do no harm. This is true of areas in southern Utah. While *Delphinium bicolor*, the low larkspur which is characteristic of the region about the experiment station at Greycliff, undoubtedly has the same poisonous properties as the other larkspurs, it does not grow in that region in sufficient abundance to cause any harm. It occurs in scattered groups of a few plants and it would be impossible for cattle to get enough in grazing to produce intoxica-

tion. In fact, from what is known of the distribution of *Delphinium bicolor* it seems probable to the authors that this species is of no economic importance in causing losses of stock. It certainly does not poison sheep and it is highly improbable that it ever grows in sufficient abundance to be dangerous to cattle.

POST-MORTEM FEATURES OF LARKSPUR POISONING.

During the season of 1909 three autopsies were made upon the station experimental animals and three upon others that were supposed to have died of larkspur poisoning. In 1910 nine autopsies were made on animals that died at the station, and in 1911 three. Generally speaking, as has been noted elsewhere, if animals found dead upon the range are lying upon uneven ground, the head will be found lower than the rest of the body. This was true also of the animals that died in the corrals, and is probably explained by the fact that as the animals throw themselves about they get their heads lower and are unable to turn themselves back.

Generally, too, the animal dying upon the range is found very much bloated. It is very difficult to determine the post-mortem condition of range animals, as it is seldom possible to make autopsies immediately after death, and as the number of animals autopsied at the station was small the facts observed can not be supposed to demonstrate conclusively the detailed conditions of larkspur poisoning.

In nearly all cases the heart was found in diastole and filled with blood. Commonly, the walls of the heart were more or less congested and frequently with petechiæ. The peripheral veins and venous system of the abdomen were found congested. In stripping the skin from the animal it was usual to find the veins immediately beneath the skin very much swollen. The lungs were congested, and the kidneys acutely congested. There was generally a hyperemic condition of the central nervous system, as would be expected from the general condition of the circulatory organs. Commonly the inner walls of the trachea and sometimes of the bronchi were very deeply congested. Inflammation was almost invariably present in the rumen near the esophageal opening. In some cases the walls of the second and third stomach were inflamed and in practically all cases the pyloric end of the fourth stomach. This inflammation extended in greater or less degree through the duodenum, jejunum, and ileum. In three cases the colon was inflamed. In five cases the wall of the cecum was inflamed, and in most cases the walls of the rectum.

To summarize the noticeable points brought out by the post-mortem examinations of these animals, there was marked inflammation in all parts of the alimentary canal, marked congestion of

the kidneys, and distinct congestion of the walls of the heart, associated with a general congestion of the peripheral circulation.

TOXICITY OF DIFFERENT PARTS OF THE PLANT.

In the course of the experiments careful notes were made with regard to the part of the plant fed to the animals. Some animals were fed leaves and stems; others leaves, stems, and flowers; others the tops with the seed; and, in the case of *Delphinium menziesii* and *Delphinium andersonii*, some were fed the roots alone.

There is a widespread belief among the stockmen of Colorado that the roots of *Delphinium menziesii* are much more poisonous than other parts of the plant. It is said that cattle are much more likely to be poisoned after a rain, when they can pull up the plants by the roots and devour a large quantity of the latter. In the summer of 1909 special attention was paid to the feeding of roots to the cattle. Two animals—Nos. 92 and 117—were fed roots alone of *Delphinium menziesii*. No. 92, in 2 days, ate an equivalent of 2.47 pounds per 1,000 pounds of weight, and No. 117, in 1 day, ate 2.1 pounds of roots without any symptoms of poisoning. These quantities, to be sure, were not very large; but it is highly improbable that an animal upon the range would ever be able to consume as much. The stem of *Delphinium menziesii* is quite brittle and, while it is entirely possible to pull up the roots by the stems while the soil is moist, the larger part of them, as was proved by experiment, will break, and it is improbable that cattle in their grazing will get any considerable number of roots. These experiments would seem to prove that the roots of *Delphinium menziesii* are not violently toxic. The roots of *Delphinium barbeyi* are long and tough and are never pulled up by stock, so that for grazing they need not be considered. The feeding experiments with *Delphinium menziesii* throughout the season of 1910 were of the whole plant, and there was no reason to think that the roots were especially toxic. In the experimental feeding of the roots of *Delphinium andersonii*, given in detail on page 58, only sheep were used, so no results were reached as to the comparative toxicity of different parts of the plant, as there is no evidence that sheep are poisoned by any part of the plant. The experiment was significant as indicating that in all probability sheep are not injured by the roots of this plant.

The charts (figs. 6, 7, 8, 9, and 10) for the feeding of both *Delphinium barbeyi* and *Delphinium menziesii* show quite clearly the greater toxicity of the seeds. It will be noticed from the charts that in the feeding of plants at the time when seeds were present a smaller quantity was necessary in order to produce symptoms of poisoning. In this connection, the case of heifer No. 633 is especially interesting. This animal was found dead in the pasture September 2, 1911.

Although *Delphinium barbeyi* was common in the pasture, no trouble had been experienced from this source, probably because there was an abundance of good feed. Moreover, none of the experimentally fed animals had been poisoned since August 8, on account of the diminished toxicity of the plants. The autopsy showed that No. 633 had died of asphyxia, as it had vomited, and the stomach contents were found in the larynx and trachea. As the animal had been dead for two or three days, the autopsy was unsatisfactory, but, so far as it could be made, showed conditions typical of larkspur poisoning. A careful examination of the contents of the rumen demonstrated the presence of a large amount of stems and seeds of *Delphinium barbeyi*. This, then, was clearly a case of larkspur poisoning in which the seeds were the most important factor, for it was too late in the season for the leaves to produce poisoning.

AGE OF PLANTS AS AFFECTING TOXICITY.

From a careful examination of the charts for the feeding of *Delphinium barbeyi* and *Delphinium menziesii* certain facts are brought out quite clearly in regard to seasonal changes in toxicity. If an average curve were made for the charts of *Delphinium barbeyi* feeding in 1909, 1910, and 1911 (figs. 6, 7, 8, 10, and 11), it would be found that the quantity necessary to produce poisoning increases progressively from the first of the season until the time when seeds are formed in the plants. Taking into account the length of time during which the plant was given in individual cases, the apparently aberrant cases of very large quantities in these years are easily explained, as, in those cases, by reason of the prolonged feeding, there was more or less elimination of the poison.

It is a striking fact that the smallest quantity needed to produce poisoning was in the earliest cases. It seems quite clear that *Delphinium barbeyi* progressively loses toxicity after blossoming until the time when the seeds are formed. At this time the leaves and stems are not particularly toxic and if the seeds were disregarded, the curve would indicate diminished toxicity from early in the season until the middle or last of August, at which time on the Colorado ranges the plant becomes perfectly harmless.

As a matter of fact, stock on the range do not eat the seeds of *Delphinium barbeyi* to any extent, so that the fact that the seeds are especially toxic has little practical bearing so far as the stockmen are concerned. It may be stated as a general fact that after the middle or latter part of August, depending upon the season, *Delphinium barbeyi* ceases to be poisonous, and under ordinary range conditions in Colorado few cases of poisoning occur after the middle of July. Not only does it cease to be injurious, but it has been noticed that

late in the season during the month of September the leaves of *Delphinium barbeyi* are eaten by stock with great apparent eagerness. Before the season is concluded, where a range is grazed with any thoroughness, nearly all the leaves of *Delphinium barbeyi* will be stripped from the stems by the grazing cattle and eaten with no resulting harm.

The chart for *Delphinium menziesii*, figure 9, determined by the experiments of 1910, would seem to indicate that the quantity necessary to poison stock grows smaller as the season progresses. This probably is explained by the fact that in the latter part of June many of the plants have formed seed and that these seed pods were eaten by the cattle. If the plant has greater toxicity in the latter part of the season than in the earlier, as this chart would seem to indicate, it is doubtless explained in this way, for the seeds are formed in *Delphinium menziesii* while the leaves are still more or less green and doubtless attractive to a grazing animal.

The principal inferences from these facts in regard to the variation of toxicity with the age of the plant may be summed up as follows:

First, *Delphinium menziesii* is poisonous during the whole period of the life of the plant. Immediately upon the formation of the seed, the plant withers and disappears, so that it no longer is a factor in poisoning. If *Delphinium menziesii* does more harm in the early season than in the latter period of its existence, it must be due to the fact that, because of the poorer feed earlier in the season, cattle may eat more of it than they do later when the grasses have sprung up.

Second, *Delphinium barbeyi* in Colorado is poisonous from early spring until the middle or last of August, its toxicity after blossoming gradually diminishing until it entirely disappears and the plant can be eaten with impunity by cattle. It would appear that it is vastly more toxic early in the season and without doubt it is in the month of June that the most harm is done by this plant. The fact of the great toxicity of the seeds has little practical importance because cattle rarely feed upon them. So far as inferences may be drawn from a somewhat limited experience it would appear that *Delphinium cucullatum* varies in its toxicity as does *Delphinium barbeyi*.

Investigations in the Sierras, where the common larkspur is *Delphinium glaucum*, show a somewhat different condition from that noted in Colorado. Here the snowfall is very heavy and the snow does not disappear in some localities until very late in the season, making the period of blossoming late. Larkspurs may be in blossom as late as September, and the period of possible poisoning of cattle is extended through nearly the whole grazing season.

It should be borne in mind also that in any given region, climatic conditions vary. In a dry, hot season the larkspurs will ripen earlier, while in a cold, wet season the time of blossoming and forming of seed may be much delayed.

Referring to the work of Loy, Heyl, and Hepner, which is noticed on page 11, it will be seen that their results in regard to the toxicity of different parts of the plant correspond fairly well to the results obtained in the field experimentation. It may be noted that the large content of alkaloid in the leaf and stem of *Delphinium geyeri* as compared with the other species may be accounted for by the fact that the plant was collected early in the season before blossoming, at the time when it might be expected to be more toxic, while the *Delphinium glaucum* was collected at the full maturity of the plant and very likely at a time when the toxicity was beginning to diminish.

ANTIDOTAL TREATMENT OF CASES OF LARKSPUR POISONING.

The early treatment of larkspur poisoning at the Mount Carbon station was based upon the recommendations in the literature of the subject. Wilcox, 1897, page 45, recommends the use of atropin sulphate, stating that he had had good results with sheep in Montana. Chesnut and Wilcox, 1901, pages 72 and 80, recommend atropin for counteracting the physiological effects, and suggest that alcoholic stimulants and ammonia can be used to advantage. They recommend also permanganate of potassium and sulphate of aluminium. Crawford, 1907, pages 9 and 10, states that poisoning takes place more quickly when elimination is interfered with, as, for example, by tying the ureter of the animal experimented upon. It seemed best, therefore, in the experimental work at Mount Carbon to make trial of atropin, potassium permanganate, and caffeine sodio-benzoate. The latter substance was used partly because it is a heart stimulant and partly because it is a diuretic, on the assumption that stimulation of the kidneys might aid in the elimination of the poison. In several cases during the first season's work at Mount Carbon these remedies were used, and while all of the animals to which the remedies were given recovered, there was reason to think that none of the remedial measures were especially effective. On comparison of the animals treated with those not treated, it could not be shown that there were any advantageous effects from the administration of these remedies.

Reference may be made here to the experiments detailed in pages 41 to 43 of United States Department of Agriculture Bulletin No. 125, "Zygadenus, or Death Camas," in which it is shown that good results can not be reasonably expected from an antidotal remedy like potassium permanganate, given per os to a ruminant, inasmuch as the antidote is not likely to come in contact with any considerable

quantity of the poisonous substance unless it is given in many doses repeated at very frequent intervals.

It was noticed early in the work of 1909 that all the poisoned animals were very constipated, and the question was raised whether the removal of this condition might not either prevent the poisoning or predispose the animals to recovery. Cowboys upon the range have remarked that whenever animals commence to defecate recovery is assured. Therefore if the animals were so treated as to keep up a free movement of the bowels, it might be possible to prevent the poisonous action of the larkspur. To test this, No. 602 was brought into the corral on September 8, 1909, for experimental feeding. Feeding of *Delphinium barbeyi* was commenced on September 9, using the leaves, stems, and fruit of material that had been collected at Kebler Pass. Although this material was mature, it was green and fresh. Feeding was continued to September 16. During this time the animal, which weighed about 450 pounds, ate 388.25 pounds of the plant, or, on the basis of 1,000 pounds of weight, 862.8 pounds. On September 9, 10, 11, 12, 13, 15, and 16 she received 4 ounces of magnesium sulphate in the drinking water. In spite of the large quantity of larkspur eaten the animal showed not the slightest effect of poisoning. The bowels were kept rather more loose than normal. Inasmuch as the general results of the experimental work show that the larkspur as it grows older loses much of its toxicity, the question was raised whether the failure to poison this animal was not due to the fact that the larkspur was old and had perhaps lost some of its poisonous properties. In order to test this No. 112 was brought into the corrals on September 15, and feeding was commenced on September 16 of material obtained from the same place as that fed to No. 602. She was fed during September 16 and 17 79½ pounds, or, on the basis of 1,000 pounds of weight, 130 pounds. At 5.35 p. m. on September 17 she was found down in the corrals. At 5.38 she was disgorging material from the rumen, this material consisting of larkspur and water, part of it passing up through the nostrils and interfering with her breathing. At 5.42 she was raised up in order that the trachea might be less likely to be filled with the vomited material. She was hardly able to hold up her head. There was some twitching of the flank muscles and the muscles of the forelegs. Respiration at this time was very slow and shallow. The pulse could not be found at all. At 5.48 she was dead. This animal during the feeding was very much constipated. She received larkspur from the same localities as that fed to No. 602, and the material was in practically the same condition. It should be noted, too, that not only did No. 602 receive a much larger total quantity of larkspur, but the daily feeding also was very much

larger. On one day this animal received almost twice as much as was given to No. 112 on the second day when it became ill.

While these two cases can not be considered as furnishing positive proof that the administration of magnesium sulphate will prevent the action of larkspur, the results were very significant.

In connection with this case, comparisons may be made with some others. No. 606, a heifer, weighing about 450 pounds, belonging to Otis Moore, was fed, between August 28 and September 6, 195 pounds of *Delphinium barbeyi*, or, on the basis of 1,000 pounds of weight, 434.8 pounds. Part of this material was collected at Kebler Pass and was green. A smaller part, about 50 pounds, was collected near the station and was older and drier. This feeding was of leaves and stems without the seeds. She was given 4 ounces of magnesium sulphate in the drinking water on August 30 and September 3. No poisonous effects were noticed.

At the same time, August 28 and 29, No. 605 was fed 29½ pounds, or, on the basis of 1,000 pounds weight, 66.5 pounds, and became sick. The material fed was of stems and seeds of *Delphinium barbeyi*. It should be borne in mind, however, in comparing Nos. 605 and 606, that the seeds are more toxic than the leaves and stems, as has been shown elsewhere, and that it is possible the result in the case of No. 605 may have been caused by the larger number of seeds in the feeding.

With this, however, may be compared No. 98, which, between September 18 and 25, received 357.25 pounds, or, on the basis of 1,000 pounds' weight, 776.6 pounds of *Delphinium barbeyi*, collected at Kebler Pass. This material included not only stems and leaves, but the seeds. The animal ate a very large proportion of its own weight of larkspur. Four ounces of magnesium sulphate in its drinking water were given every day between September 18 and 25, inclusive, the effect of this being to keep the action of the bowels in very nearly a normal condition. The animal was not affected at all by the poisonous material eaten.

Summing up these cases, then, it would appear that it is very probable that the injurious effects of larkspur eating might not appear if means were taken to produce free movement of the bowels in the animals feeding upon the plant, and it indicates also that if some remedy could be used which, in the beginning of the poisoning, would quickly stimulate the intestinal excretion it might serve to save the lives of the animals.

Inasmuch as the work of 1909 at the Mount Carbon station brought out very clearly the fact that one of the most prominent symptoms connected with larkspur poisoning was constipation, and also showed very clearly that death resulted primarily from respiratory paralysis,

in planning for the remedial work of 1910 it seemed wise to use substances which would probably counteract these most pronounced symptoms. It was at first thought that some combination might be made with barium chlorid, using the barium chlorid for the purpose of getting a quick evacuation of the intestines, combining with it caffein or digitalis to relieve the depressing effect which barium has upon the heart and adding strychnin to serve as a respiratory stimulant. Tablets were prepared of various combinations for the summer's work.

One case of *Delphinium menziesii* poisoning was treated with barium chlorid, caffein, sodio-benzoate, and strychnin nitrate, and died. One case of *Delphinium barbeyi* was treated with the same combination and died. It was not clear, therefore, that there were any beneficial results from this treatment, and as it was found difficult to handle the combination without hot water for solution it was abandoned as impracticable for field use.

A hypodermic injection was used of physostigmin salicylate, pilocarpin hydrochlorid, and strychnin sulphate. This combination dissolves very readily and can be used in a comparatively small amount of water. The treatment was used in 32 cases of larkspur poisoning with a total of 4 deaths. One fatal case was known to be due to an overdose of strychnin and two received too small a dose of physostigmin. One case died, apparently, in spite of the remedy. Fifteen were allowed to go without treatment, and of these 6 died. This seems to make a good showing for the remedy, although, of course, too much stress must not be put on the statistical results of a comparatively small number of cases. It is presumed that probably a larger proportion of range animals would die than of corral-fed cases, for the latter, even if no remedy was given, are cared for and put in a favorable position for recovery.

Excluding the animal killed by strychnin and the 2 receiving too small a dose, there was only 1 death in 29 treated cases; in other words, there was 96.54 per cent of recoveries. While this percentage might not hold in a larger number of cases, there is good reason to believe that most cases of larkspur poisoning may be cured if this treatment can be applied promptly.

In comparing the effects obtained in the different cases it was found that the best results in animals weighing 500 to 600 pounds were reached by using the following formula of this remedy:

Physostigmin salicylate.....	1 grain.
Pilocarpin hydrochlorid.....	2 grains.
Strychnin sulphate.....	$\frac{1}{2}$ grain.

As much as 1 grain of strychnin was used in some cases, but it seems probable that this is too much. There was little doubt that an overdose was given to No. 613, a fatal case of *Delphinium barbeyi*.

poisoning in 1910, as there were distinct symptoms of strychnin poisoning. Smaller doses were tried with some of the cases of 1911; but they were less effective and the two fatal cases in this season, when this remedy was used, are considered as due to the use of an insufficient amount of the remedy. It is possible that a heavier dosage of physostigmin salicylate and pilocarpin hydrochlorid might be used, but experience seemed to show that the pain connected with the more rapid action of this remedy more than counterbalanced its advantage. The results of the summers of 1910 and 1911 appeared to show quite conclusively that the hypodermic injection of this combination would aid in the recovery of most animals. The attempt was made to use arecolin in place of the physostigmin and pilocarpin but the results were very unsatisfactory.

It was found that a distinct benefit resulted from the use of hypodermic injections of 20 cubic centimeters or more of whisky or a corresponding amount of 50 per cent alcohol. This stimulant was given to tide over a time when the animal might otherwise collapse. It was not found desirable to give the whisky in all cases but only as the symptoms seemed to demand it.

In passing, perhaps a word should be said in regard to the ordinary remedy of bleeding used among the stockmen for larkspur poisoning. This was not attempted in the station work, because there seemed to be no good reason for the proceeding. It is barely possible that at the critical stage of larkspur poisoning, with the heart about to stop, bleeding might stimulate it to further action. It was not found, however, in the station experiments that the symptoms at any time definitely indicated this as a desirable measure. Indiscriminate bleeding for larkspur poisoning is probably worse than useless and does much more harm than good. Among stockmen the claim is frequently made that 50 per cent of the sick cases may be saved by bleeding. It may be questioned whether this number might not recover without any treatment. Dr. Sanford, of Gunnison, Colo., a physician of long and successful experience in a stock country, states that he has bled a large number of animals poisoned by larkspur and has no evidence of beneficial results.

Bleeding is the common remedy used by stock people for many of the ills affecting their animals, and is considered especially efficacious in cases of illness resulting from eating poisonous plants. While it did not seem worth while to test it out in the larkspur poisoning of cattle, it was used experimentally with sheep poisoned by *Zygadenus* (death camas), as stated in Bulletin 125, with no benefit.

Summarizing, then, the work of the station upon remedies, no definite advantageous results were obtained with potassium permanga-

nate, atropin, or the combination of barium chlorid with caffein, sodio-benzoate and strychnin. The combination of physostigmin salicylate, pilocarpin hydrochlorid, and strychnin sulphate, used hypodermically, and supplemented as symptoms demand by hypodermic injections of whisky or dilute alcohol, would seem in the majority of cases to produce beneficial effects. These remedies can be easily administered by stockmen upon the range, as they can be carried in solution in small compass and administered by the hypodermic syringe, with the use of which most stockmen are familiar. It can not be too strongly stated that when cattle fall from larkspur poisoning no attempt should be made to get them upon their feet, or, if they get upon their feet themselves, care must be taken that they should not be hurried under any circumstances. Many of the animals when poisoned, if allowed to lie quietly with no other attention than to be turned so that the head will be higher than the rest of the body, will recover.

As has been stated elsewhere, bloating seldom occurs in cases of larkspur poisoning. If it does, it should be relieved by paunching, and every stockman should be provided with a trocar to perform this operation.

METHODS OF PREVENTING LARKSPUR POISONING.

It is recognized that under ordinary range conditions many cases of larkspur poisoning occur which can not be prevented. The cattle are not under direct observation and may not be seen for weeks or months, and the first intimation of trouble is when the rider, in going over the range, finds bodies of animals that may have died long before. There is no opportunity to apply a remedy. It is possible, however, to save many cattle by proper handling in accordance with the conditions of the ranges upon which they are grazed.

From the fact that the low larkspur dies early in July and ceases to be a factor in poisoning, it is very evident that if the cattle can be kept away from this plant until about July 1 there probably will be no fatalities. This has been recognized very generally by the stockmen. In some localities on the western slope of the Rocky Mountains in Colorado "riding for poison" is a regular business among the stockmen during the month of June. By this "riding" the cattle are kept below the poisonous area until after the plants blossom. In some localities, also, through the instrumentality of the Forest Service, drift fences have been erected for the same purposes.

There seems to be no question that if cattle can be kept away from the areas of low larkspur until the plant matures there will be no losses, but if they are permitted to graze freely upon these areas loss is almost certain to occur. These losses, of course, will be greater

when the grasses are less conspicuous. Just so far as the larkspur is more evident than other forms of forage plants, it is sure to be eaten in larger quantities and will produce correspondingly greater harm.

The tall larkspur is especially dangerous in Colorado during the months of May and June. After it springs up in the early part of the season it grows in large tufts of rather attractive appearance and extends above the forage plants. It is at this time that it is most likely to be eaten by cattle. In narrow valleys where the larkspur is quite abundant, if cattle collect in the early part of the season to graze, they are almost certain to take a considerable quantity of the larkspur with more or less losses resulting. It is entirely feasible in many of these small canyons to clear out the major part of the larkspur and thus prevent poisoning, and it is definitely recommended that in such restricted areas the plant be dug out.

Experimental work carried out upon the range has shown that the larkspur can be killed by cutting the root 2 or 3 inches below the surface of the ground, and this has been done by the Forest Service in some localities on a somewhat large scale. Complete eradication of the plant, however, is impossible, and in many places it is economically unprofitable to dig it out. In some valleys it is so scattered among the willows that it is difficult to approach it, and on some ranges it is distributed so widely and in places so difficult of access that the expenditure of labor necessary to destroy the plant would exceed the value of the range. The practicability of digging out larkspur on any range depends upon the characteristics of that particular range, and can not be decided without a careful examination of local conditions.

It was found, while investigating the conditions of larkspur poisoning in the Sierras, that in many especially harmful regions the heavy growth of larkspur is confined to particular valleys, or, in some cases, to a very limited area in a valley. Some of these valleys can be easily fenced off and used for horses rather than for cattle, and the small isolated areas can be cleared of most of the larkspur at a small expenditure of time and money.

When cattle are driven hurriedly from one range to another they are much more apt to become poisoned, as it is well known that hungry cattle when hurried along will eat the most conspicuous plants, and under such circumstances quite large losses may occur. It is evident, then, that in handling cattle in areas where the tall larkspur is abundant, particularly early in the season, great care should be taken that they should not come upon these areas when they are especially hungry. The subject of the proper handling of range animals in order to avoid poisoning is treated more specifically

in Farmers' Bulletin No. 720, Prevention of Losses of Live Stock from Plant Poisoning.

After the plant has matured, as has been shown elsewhere, its toxicity diminishes, and cattle, finding at the same time an abundance of other more attractive feed, eat very much less of the larkspur so that the danger of poisoning is very slight, and in the fall, after the plant begins to dry, cattle may and do eat it in large quantities with impunity.

It is generally considered by stockmen that poisoning is more likely to occur immediately after a rain, or even when the plants are wet with dew. There seems to be no reasonable explanation of the supposed fact of the greater toxicity of the plant when wet. It seems possible, however, when cattle are feeding hastily in a larkspur area after a rain, that rather than thrust their heads and faces into the wet grass they may eat more of the higher plants; in this way they would consume more of the larkspur and consequently become poisoned. Cattle, too, in the time of a storm gather together in the valleys and under trees where larkspur is very abundant, and doubtless eat more of it on this account.

Probably, also, when cattle are handled upon a supposed poisonous area it would aid somewhat in preventing loss if pains were taken to make sure that none of them were constipated. This probably could be accomplished, where cattle are watered at specific places, by the use of a small amount of magnesium sulphate or sodium sulphate in the drinking water.

GENERAL SUMMARY.

1. The larkspurs from very ancient times have been recognized as poisonous plants, but complaints of stock poisoning by these plants have been confined almost entirely to the mountain ranges of western North America, where heavy losses have been reported, especially among cattle.

2. It is rarely possible to recognize macroscopically larkspur material in the stomach contents of cattle. By means of microscopic sections of stems, however, not only can *Delphinium* be distinguished from other plants but groups of the genus can be distinguished from each other. The genus falls into six different types of stem structure.

3. Experimental feeding of larkspur was carried on for three seasons at Mount Carbon, in Gunnison County, Colo. In this work four species of *Delphinium* were used which have been identified as *Delphinium barbeyi*, *D. menziesii*, *D. andersonii*, and *D. robustum*. A large number of animals were used in this work, including horses, cattle, and sheep. Similar feeding experiments were conducted

during one season at Greycliff, Mont., on *Delphinium cucullatum* and *D. bicolor*.

4. These experiments showed that the larkspurs are poisonous to cattle and horses but not to sheep. Horses, however, in pastures or upon the range do not eat enough of the plants to produce any ill effects, so that losses of stock from larkspur poisoning are confined to cattle.

5. The low larkspurs are poisonous during the whole life of the plants, but inasmuch as they disappear early in July, cases of poisoning are confined to the months of May and June.

6. The tall larkspurs live through the summer season, appearing in early spring. They are most poisonous in their early stages. After blossoming the toxicity gradually diminishes and disappears and the plant dries up, although the seeds are very toxic. Most of the cases of poisoning in Colorado occur in May and June, with sporadic cases in July. In other localities where the larkspurs blossom later poisoning may occur as late as August or even September.

7. While definite feeding experiments have been performed upon only a few species of larkspur, it may be assumed, from the knowledge of plant poisoning upon the ranges, that other species have the same properties as those experimented upon and that feeding upon them produces the same results.

8. The experimental work and the autopsies showed a clearly defined line of symptoms and certain definite pathological results.

9. The feeding showed that there was no marked difference in toxicity between the different species of larkspurs and that the quantity necessary to produce effects varied within rather wide limits, but that, generally speaking, a quantity equal to at least 3 per cent of the weight of the animal was necessary to produce poisoning.

10. From somewhat extensive experimental work on antidotes it was found that beneficial results could be obtained by using, hypodermically, injections of physostigmin salicylate, pilocarpin hydrochlorid, and strychnin sulphate, followed by hypodermic injections of whisky when needed.

11. Poisoning upon the range may be prevented in some cases by digging up the tall larkspur when the greater number of plants is confined to comparatively limited areas. In other cases the handling of the cattle in such a way that they will not have an opportunity to feed upon the larkspur may prevent losses. In the case of *Delphinium menziesii* it is desirable that the cattle should be kept away from the ranges where this plant grows in abundance until about the 1st of July, when the plant dies. *D. barbeyi* loses its toxicity after blossoming, so that a range with this plant is safe for cattle in the late summer and fall. It should be remembered, however, that local

and climatic conditions may delay the time of blossoming, so that no arbitrary date can be given when a range is safe. *D. bicolor* probably never grows in sufficient quantities to be dangerous as a poisonous plant. Inasmuch as the experimental work seems to show quite conclusively that sheep may feed upon larkspurs with entire impunity it is desirable in some cases, where there is an especial abundance of larkspur, to use the ranges for sheep rather than for cattle or to combine sheep grazing and cattle grazing in such a manner as to keep the areas of low larkspur eaten down by the sheep.

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PROFESSIONAL PAPER

April 24, 1916.

MANUFACTURING TESTS OF COTTON FUMIGATED WITH HYDROCYANIC-ACID GAS.

By WILLIAM S. DEAN, *Assistant in Cotton Testing.*

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INTRODUCTION.

The spinning tests herein described were suggested by a joint committee of cotton manufacturers and officials of the Federal Horticultural Board, who met and discussed plans of preventing the introduction into the United States of the pink boll worm¹ with the importations of foreign-grown cotton. As hydrocyanic-acid gas had been found by that Board to be a practicable and successful fumigating agent² in the destruction of these pests, even though the larvæ were in the center of a compressed bale of cotton, it was decided that manufacturing tests should be made to determine whether the fumigation by this agent would cause any injury to the cotton fibers.

SPINNING TESTS.

The manufacturing tests were conducted by the United States Department of Agriculture, under the direct supervision of the Office of Markets and Rural Organization. Through the courtesy of the president and manager the tests were made at the New Bedford

¹ Hunter, W. D., The Pink Boll Worm. Unnumbered publication. U. S. Department of Agriculture, Bureau of Entomology, August, 1914.

² For a description of this method of fumigation see U. S. Department of Agriculture, Federal Horticultural Board. Service and regulatory announcement No. 21, 1915.

NOTE.—This bulletin should be of interest to manufacturers and dealers in foreign-grown cotton and cotton yarns, also indirectly of interest to the domestic producers, manufacturers, and dealers in all staple cottons.

Textile School, New Bedford, Mass., on two separate lots of cotton, a portion of each lot having been fumigated with hydrocyanic-acid gas under the supervision of the Federal Horticultural Board. In each lot the fumigated cotton was compared with nonfumigated cotton of the same lot.

The principal points taken into consideration during the spinning tests to determine whether the fibers were injured by the fumigation were (1) the percentage of waste, (2) the spinning qualities, (3) the tensile strength of the yarn. During the laboratory tests the following points were considered: (4) The bleaching properties of both the cotton and yarn, (5) the dyeing properties of the cotton and yarn, and (6) the mercerizing properties of the yarn.

In addition to the manufacturing tests, made by the Department of Agriculture, a number of manufacturing firms that regularly use foreign-grown cotton conducted tests in order to ascertain whether the fumigation of cotton with hydrocyanic-acid gas proved detrimental to their product. These tests were conducted in cooperation with officials of the Department of Agriculture.

Several manufacturing companies also sent yarns to Washington which were tested in the yarn testing laboratory of the Department of Agriculture for tensile strength. Two of these firms sent complete reports which included the comparative waste percentages of fumigated and nonfumigated cotton as found by them.

STOCK OF COTTON.

In the tests conducted by the Department of Agriculture the first lot consisted of two 50-pound samples, one taken from a fumigated bale and one from a nonfumigated bale. Both bales were of Sakellaridis Egyptian cotton $1\frac{1}{4}$ inch in length of staple. The fumigated bale was fumigated with hydrocyanic-acid gas on at least five different occasions in a vacuum of 27 inches. The amount of sodium cyanide employed varied from 3 to 10 ounces per 100 cubic feet of chamber space with exposures ranging from thirty minutes to one hour. The volume of gas which penetrated this bale was fully ten times as much as that ordinarily used in accordance with the regulations prescribed by the Federal Horticultural Board. All other fumigated cotton referred to in this publication was exposed to hydrocyanic-acid gas in the presence of a 20-inch vacuum with 3 ounces of sodium cyanide per 100 cubic feet of chamber space with an exposure of one-half hour. The second lot consisted of 50-pound samples from each of six bales of Sakellaridis Egyptian cotton of $1\frac{1}{2}$ inches in length of staple.

Three of the bales were fumigated and three bales were nonfumigated. In the selection of the fumigated and nonfumigated cotton a careful comparison was made of grade and staple in order to secure equal values.

A few samples of fumigated and nonfumigated Peruvian and Chinese cottons were secured from the mills and chemical laboratory tests were made on these cottons in the department of chemistry and dyeing of the New Bedford Textile School.

METHODS OF COMPARISON.

Each bale was given a mark so that it could not readily be identified while in the manufacturing processes as to whether it had been fumigated. The fumigated and nonfumigated cottons of each lot were opened and left standing overnight. They were run through the machines under the same conditions of speeds and settings, and where possible the fumigated and nonfumigated portions of each lot were placed side by side on the same machine, advancing together through the various processes of manufacture. Between each run the machines were cleaned thoroughly. Total weights were taken before and after the cotton was fed into the opener, finisher, cards, and combers respectively. Records of humidity were taken hourly and the humidifiers regulated accordingly, keeping the relative humidity as nearly uniform as possible for the respective lots.

WASTE PERCENTAGES.

Table I gives the comparative waste percentages of the fumigated and nonfumigated cotton.

Lots No. 1 and No. 2 represent respectively the 1½-inch staple and the 1½-inch staple, fumigated and nonfumigated cotton given separately, which were tested at the New Bedford Textile School, New Bedford, Mass. Lots No. 3 and No. 4 represent a digest of the reports received from the two manufacturing firms.

TABLE I.—*Waste percentages.*

[Based on net weight of cotton fed into each machine.]

Kind of waste.	Lot No. 1.		Lot No. 2.		Lot No. 3.		Lot No. 4.	
	Fumi- gated.	Non- fumi- gated.	Fumi- gated.	Non- fumi- gated.	Fumi- gated.	Non- fumi- gated.	Fumi- gated.	Non- fumi- gated.
Opener:								
Visible—								
Dust room.....	0.67	0.25	0.46	0.33	.....	.....	.....	.....
Motes and fly.....	1.06	1.50	.87	.67	.....	.....	1.45	1.47
Total visible.....	1.73	1.75	1.33	1.00	0.65	.53	1.45	1.47
Invisible.....	2.53	1.75	.29	.62	.83	.55	.05	.03
Total visible and invisible..	4.26	3.50	1.62	1.62	1.48	1.08	1.50	1.50
Finisher:								
Visible—								
Dust room.....	.14	.14	.09	.09	.....	.....	.....	.....
Motes and fly.....	1.43	.96	.74	.65	.....	.....	.47	.48
Total visible.....	1.57	1.10	.83	.74	.78	.63	.47	.48
Invisible.....	1.14	.13	.13	.04	1.15	.61	.03	.03
Total visible and invisible..	1.43	1.23	1.01	.78	1.93	1.24	.50	.51

¹ Invisible gain, not loss, as a result of weather conditions.

TABLE I.—*Waste percentages*—Continued.

Kind of waste.	Lot No. 1.		Lot No. 2.		Lot No. 3.		Lot No. 4.	
	Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.
Cards:								
Visible—								
Flat strippings.....	3.26	3.49	4.59	4.44	6.44	5.92	3.67	5.61
Cylinder and doffer strippings.....	.93	1.02	1.33	1.36	1.05	.90	.26	.51
Motes and fly.....	1.72	1.01	1.01	1.22	3.26	2.25	1.85	1.85
Total visible.....	5.91	5.52	6.93	7.02	10.75	9.07	5.78	7.97
Invisible.....	1.09	2.03	.50	.27	.91	2.22	.09	.19
Total visible and invisible..	7.00	7.55	7.43	7.29	11.66	11.29	5.87	8.16
Comber:								
Visible.....	11.68	12.21	13.55	13.62	19.48	18.88	16.10	15.28
Invisible.....			.31		1.27	.10	.15	1.66
Total visible and invisible.....	11.68	12.21	13.86	13.62	20.75	18.98	16.25	16.94

The figures given in Table I are based on the net weight of stock fed into each machine. It will be observed that there is no decided indication of the superiority of either the fumigated or non-fumigated cotton. The percentages of waste fluctuate considerably, without being consistently in favor of either the fumigated or the nonfumigated stock. Similar differences would be expected to exist in the comparisons of any two bales of cotton selected for equal value.

Table II gives the total percentages of visible and invisible waste discarded by the respective waste-cleaning machines. The percentages here given are based on the net weight of cotton fed into the opener picker.

TABLE II.—*Visible, invisible, and total waste percentages.*

[Based on net weight of cotton fed into the opener picker.]

Kind of waste.	Lot No. 1		Lot No. 2.		Lot No. 3.		Lot No. 4.	
	Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.
Total visible and invisible waste pickers.....	5.62	4.69	2.61	2.39	3.39	2.31	2.00	2.00
Total visible and invisible waste cards.....	6.61	7.20	7.23	7.12	11.28	11.03	5.75	8.00
Total visible and invisible waste combers.....	10.25	10.76	12.50	12.32	10.62	16.46	14.97	15.25
Grand total visible and invisible waste.....	22.48	22.65	22.34	21.83	25.29	29.80	22.72	25.25

There is no evidence of injury to the cotton indicated by the results of the visible and invisible percentages of waste discarded. In fact, Table II shows that in every case, except lot No. 3, the grand total waste discarded from the fumigated cotton was less than that discarded from the nonfumigated cotton. Should the results have been the reverse—that is, in favor of the nonfumigated cotton to the

same extent—the effects of the fumigation might have been seriously questioned. However, since the two tests at the textile school do not disclose any material difference between these lots it is assumed that the differences shown by the mill tests are the result of technicalities.

MOISTURE TESTS.

The results of these tests were substantiated by moisture tests of the fumigated and nonfumigated cotton at the textile school, shown in Table III. The results of these tests indicate that the fumigation had no appreciable effect on the absorptive properties of the cotton.

TABLE III.—Percentages of moisture in the cotton while in the manufacturing processes.

Process.	Lot No. 2.		Difference.
	Fumigated.	Nonfumigated.	
Fed into opener.....	8.10	7.76	+0.34
Finished lap.....	8.09	7.66	+0.43
Card sliver.....	6.55	7.60	-1.05
Comber sliver.....	7.08	7.13	-0.05

SPINNING QUALITIES.

The numbers of yarn made at the textile school to ascertain the spinning qualities were 40's and 50's from the 1 $\frac{1}{4}$ -inch cotton and 10's, 20's, 30's, 40's, 50's, 60's, 80's, and 100's from the 1 $\frac{1}{2}$ -inch cotton. Close observations were made by the men who actually were running the machines and also by those supervising the work and no difference was observed in the general spinning qualities.

TENSILE STRENGTH.

In order to ascertain the tensile strength comparisons of the different lots of fumigated and nonfumigated cotton, a number of bobbins of the different numbers of yarn were sent from the textile school and the mills to the laboratory of the Office of Markets and Rural Organization of the Department of Agriculture for test purposes.

These tests were made by reeling off, in skeins of 120 yards each, the same numbers of yarn made from the different lots. The skeins were placed on racks¹ in order to keep them separate and to avoid tangling, after which they were removed one at a time in rotation and broken with a power yarn-tester, the downward stroke of the traverser moving at the rate of approximately 12 inches per minute. Hourly humidity records were taken and the humidifier was regu-

¹ Method originated by Dr. N. A. Cobb, Bureau of Plant Industry, U. S. Department of Agriculture.

lated accordingly in order to maintain as nearly as possible a constant relative humidity of 65 per cent.

Table IV gives the results of the tensile-strength tests.

Lots Nos. 1 and 2, respectively, represent the two lots of 1½-inch and 1½-inch Egyptian cotton manufactured at the textile school, while Nos. 3, 4, 5, 6, and 7 represent five lots of cotton, each manufactured by a different representative manufacturing company. The small variations in the various numbers of yarn were standardized for comparison. The differences in tensile strength, in some instances, were in favor of the fumigated and, in some instances, in favor of the nonfumigated cotton.

TABLE IV.—*Tensile strength comparisons.*

(Made in Yarn Testing Laboratory of the United States Department of Agriculture.)

Number of yarn.	Lot No. 1.		Lot No. 2.		Lot No. 3.		Lot No. 4.		Lot No. 5.		Lot No. 6.		Lot No. 7.	
	Breaking strength in pounds per skein of 120 yards.		Breaking strength in pounds per skein of 120 yards.		Breaking strength in pounds per skein of 120 yards.		Breaking strength in pounds per skein of 120 yards.		Breaking strength in pounds per skein of 120 yards.		Breaking strength in pounds per skein of 120 yards.		Breaking strength in pounds per skein of 120 yards.	
	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.
15's.....					302.11	303.9								
20's.....														
22's.....									102.30	106.45				
40's.....	39.98	37.59											108.48	102.76
50's.....	27.28	27.35											115.38	115.48
55's.....							27.51	28.20						
75's.....											24.88	26.05		
80's.....			26.45	28.05										
84's.....							8.32	7.66						

TABLE V.—*Tensile strength comparisons.*

[Made by two representative cotton mills.]

Number of yarn.	Lot No. 3—Breaking strength in pounds per skein of 120 yards.		Lot No. 4—Breaking strength in pounds per skein of 120 yards.	
	Fumigated.	Nonfumigated.	Fumigated.	Nonfumigated.
27's.....	114.8	112.8		
57's.....			30.25	30.60

It will be observed that in lot No. 3 the fumigated cotton produced the stronger yarn; in lot No. 4 the reverse was true.

SINGLE-THREAD TEST.

In addition to the tests shown in Table IV several tests were made with a single-thread testing machine.¹ The results of these tests are

¹ These strength tests were made by William Smith, professor in charge of the carding and spinning department of the New Bedford Textile School, New Bedford, Mass.

shown in Table VI. The results of the single-thread tests are recorded in ounces, while the tensile strength in pounds per skein of the yarn taken from the same bobbins from which the single-thread tests were made is also given. In all cases where the skein tests are given in connection with the single-thread tests, the yarn was taken from the same bobbins.

TABLE VI.—*Single-thread test.*

[Made at the New Bedford Textile School.]

	Number of yarn.	Lot No. 1.		Lot No. 2.	
		Fumi-gated.	Non-fumi-gated.	Fumi-gated.	Non-fumi-gated.
Ounces per single thread.....	40's.....	5.48	5.53	.....	.....
Pounds per skein 60 yards.....	40's.....	49.3	46.9	.....	.....
Ounces per single thread.....	30's.....	.....	.....	14.80	15.10
Pounds per skein 60 yards.....	30's.....	.....	.....	56.25	56.50
Ounces per single thread.....	60's 2-ply..	.....	.....	16.58	16.41
Pounds per skein 60 yards.....	60's 2-ply..	.....	.....	58.20	60.50

The single-thread tests, judged from the comparative uniformity of breaks, did not disclose any superiority, either in the yarns made from the fumigated or from the nonfumigated cotton.

Two of the mills reported their findings as to the tensile strength of the cotton yarns they manufactured. These results are shown in Table V, under lots No. 3 and No. 4.

CHEMICAL LABORATORY TESTS.

Investigations also were made in the laboratory of the New Bedford Textile School¹ to ascertain whether cotton treated with hydrocyanic-acid gas lost any of its bleaching, dyeing, or mercerizing value. The following numerical designations represent the cotton and cotton yarns used in these laboratory tests:

KIND OF COTTON.

Sample No. 1. 1½-inch Sakellaridis Egyptian—fumigated.

1a. 1½-inch Sakellaridis Egyptian—nonfumigated.

2. 1½-inch Sakellaridis Egyptian—fumigated.

2a. 1½-inch Sakellaridis Egyptian—nonfumigated.

8. Peruvian cotton, from center of bale—fumigated.

9. Peruvian cotton, from outside of bale—fumigated.

10. Peruvian cotton, from center of bale—nonfumigated.

11. Peruvian cotton, from outside of bale—nonfumigated.

12. Peruvian cotton, from center of bale—fumigated.

13. Peruvian cotton, from outside of bale—fumigated.

14. Peruvian cotton, from center of bale—nonfumigated.

15. Peruvian cotton, from outside of bale—nonfumigated.

Samples 1 and 1a, respectively, represent the fumigated and non-fumigated 1½-inch Sakellaridis Egyptian cotton, the two bales from

¹ These tests were made by Everett Hinckley, professor in charge of the department of chemistry and dyeing, New Bedford Textile School, New Bedford, Mass.

which these samples were taken being previously referred to as lot No. 1. In a like manner 2 and 2a represent the 1½-inch fumigated and nonfumigated cotton previously referred to as lot No. 2. Samples 8 to 15, inclusive, were selected from Peruvian cotton received from a manufacturing company. The cotton in samples 1, 2, 8, 9, 12, and 13 was fumigated with hydrocyanic-acid gas.

BLEACHING OF RAW COTTON.

Samples of Nos. 2 and 2a were bleached by treating as follows:

Method *a*. Not scoured. Bleached with a solution obtained by the electrolysis of salt containing 0.5 gram of chlorine per liter. In future this solution will be designated as "electrolytic chlorine."

Method *b*. Scoured in a solution containing 1 gram of soda ash in each 10 cc. then bleached as in *a*.

Method *c*. Treated with 2 per cent acetic acid and bleached as in *a*.

Finally all the samples were blued with 0.001 per cent of blue-violet acid dye.

Methods *a*, *b*, and *c* are the usual processes for obtaining white cotton for spinning except that the usual quantity of bleaching agent used was reduced in these tests in order to magnify any variation in the results obtained. No differences in the results of any of the methods on the two samples were apparent, which indicates fumigating the cotton with hydrocyanic-acid gas had no appreciable effect upon the bleaching qualities of the cotton used in any of the tests.

To test the effect of fumigation on the various bleaching agents commonly used the following tests were carried out on samples No. 2, 2a, and 8 to 15, inclusive:

Method *d*. The cotton was boiled two hours in a 10 per cent solution of soda ash and bleached cold in "electrolytic chlorine" containing 2 grams of chlorine per liter.

Method *e*. The cotton was treated as in *d* except that chloride of lime solution containing 8 grams of chlorine per liter was used as the bleaching agent.

Method *f*. The cotton was treated as in *d* except that an alkaline solution of sodium peroxide equivalent to 15 grams of chlorine per liter was used. After bleaching all of the samples were blued as in methods *a*, *b*, and *c*.

The concentrations of bleaching agent are similar to those used in practice to obtain equal bleaching value. Close examinations were made of the samples by constructing a sample sheet with the different samples placed thereon for comparison. This comparison gave no indication that fumigation of cotton alters the bleaching value.

All of these tests were carried out on all of the samples of cotton.

To confirm these results, five 1-pound samples of Nos. 2 and 2a were treated by method *d*, the following details being observed in connection with the bleaching: After scouring, the cotton was rinsed

30 minutes in cold water, squeezed, and treated 2.5 hours cold with "electrolytic chlorine," 1.46 grams of chlorine per liter; was rinsed well, treated 30 minutes in a 5 per cent solution bisulphite of soda, cold; was rinsed well, and blued with a solution containing three-fourths of a gram vat blue in 10 liters of water.

Samples 10, 11, 14, and 15 were combined into one lot, samples 8 and 9 into a second lot, and samples 12 and 13 into a third lot, and each lot was bleached by the method outlined in the previous paragraph for samples Nos. 2 and 2a.

By comparison of these samples it was evident that there was as much difference in bleaching quality between the two bales of non-fumigated cotton as there was between the bales of fumigated and nonfumigated cotton of the same quality.

DESCRIPTION OF FURTHER TEST.

Samples of fumigated and nonfumigated Chinese cotton which had been both bleached and blued by a representative cotton mill were submitted for examination. As a result of the bluing process, the sample of fumigated cotton was a more intense blue than the sample of nonfumigated cotton. On receipt, tests were made on these samples for iron to ascertain if there had been a formation of Prussian blue, due to the presence of hydrocyanic acid in the fumigated cotton, which would cause the intensifying of the color of the cotton. Negative results were obtained. The bluing matter was extracted with water until the samples were practically the same color. These water extracts were of different depths of blue. The deepest extract was then diluted until both were of the same shade of blue. The extracted cotton samples were treated again in their respective solutions. The resultant samples were of the same color.

From the above results the conclusion was reached that the increased depth of blue on the fumigated sample was because it had been treated with a greater quantity of bluing and not because of the presence of hydrocyanic acid or because of any chemical change in the fiber such as the formation of hydrocellulose.

TEST FOR THE PRESENCE OF HYDROCYANIC ACID.

Small specimens from each of the following samples, 2, 2a, and 8 to 15 inclusive, were tested for the presence of hydrocyanic acid as follows:

The sample was covered with a solution of 10 c. c. of distilled water, 5 drops concentrated sulphuric acid, 5 c. c. 2/normal ferrous sulphate and 6 c. c. normal sodium hydroxide heated nearly to a boil, then 5 c. c. 6/normal hydrochloric acid were added.

These tests gave no blue coloration which indicated the absence of hydrocyanic acid in all of the samples at the time of treatment.

BLEACHING OF YARNS.

The material used in these bleaching tests consisted of yarn made from the following samples of cotton: 1 and 1a, 2 and 2a. Samples 1 and 2 had been fumigated, and samples 1a and 2a were nonfumigated.

All four samples were treated as follows: Boiled for two hours in 10 per cent solution of soda ash at atmospheric pressure, rinsed until free from alkali, then divided into two lots, each lot containing one-half of each of the above four samples. One lot was bleached by method A, the other by method B, as follows:

Method A. Treated cold for two hours in a 2° twaddle solution of bleaching powder, containing 5.82 grams of chlorine per liter, rinsed with cold water, soured with 2 per cent solution of acetic acid, rinsed and antichlored in a 2 per cent solution of sodium bisulphite 30 minutes, then finally rinsed and blued in water containing 1 gram of vat blue in each 13½ liters.

Method B. Treated as in method A, except that a solution of electrolyzed salt containing 2.87 grams per liter of available chlorine was used as the bleaching agent.

The tensile strength and the number of the yarn of all four samples were taken before and after treatment with bleach A and bleach B with the results as shown in Table VII.

TABLE VII.—*Tensile strength of yarns before and after bleaching.*

Sample No.	Grey.			Bleach A.			Bleach B.		
	No. of yarn.	Skein breakage, 60 yards.	Single-thread breakage.	No. of yarn.	Skein breakage, 60 yards.	Single-thread breakage.	No. of yarn.	Skein breakage, 60 yards.	Single-thread breakage.
1.....	26.4	44.8	10.9	29.2	36.8	8.7	29.4	44.1	10.4
1a.....	26.4	45.7	10.9	29.2	39.4	8.9	29.4	43.8	9.7
2.....	41.5	42.4	9.8	47.2	27.7	7.9	46.5	34.6	8.9
2a.....	41.5	43.2	9.8	47.2	29.3	8.0	46.5	39.0	9.1

In this table the tensile strength¹ is given in pounds for the skein breaks and in ounces for the single-thread breaks. The skeins were taken from the same bobbins of which the single threads were tested. From the comparisons of these figures it will be seen that the differences in strength between the fumigated and nonfumigated cotton are so small that it would be unsafe to say that these yarns contained in them any substance such as acids that would reduce the tensile strength of the yarn by releasing the bleaching agent too rapidly.

DYEING OF YARNS.

Portions from all of the four samples of yarns, namely, 1, 1a, 2, and 2a, were bleached according to method A and method B, except that they were not blued. Instead some of the portions were dyed pink and some were dyed blue with both direct and basic dyes.

¹ See footnote, p. 6.

DIRECT DYES.

Method of application.—Dyed in a bath containing 0.1 per cent benzo rhoduline red B, 5 per cent of salt, 0.5 per cent soluble oil. Volume of dye bath equals 25 times the weight of the goods. The goods were entered into the dye bath cold and temperature raised to a boil in 30 minutes, boiled 15 minutes, and allowed to cool in the bath 15 minutes. To obtain the light blue the goods were dyed in the same manner, except 0.1 per cent benzo fast blue BN was used instead of the benzo rhoduline red B.

BASIC DYES.

Method of application.—Mordanted in a solution containing 0.015 of a gram of tannic acid in each 100 cc. The goods were entered into the dye bath cold and temperature raised to 190° in 45 minutes, then allowed to cool overnight, rinsed and treated cold for 15 minutes in a bath containing 0.01 of a gram of tartar emetic.

The pinks were dyed in a bath containing 0.05 per cent of rhoduline red B, 0.5 per cent of acetic acid, cold 30 minutes, then raised to 140° during 30 minutes. The blues were dyed as the pinks, except that 0.05 per cent of methylene blue BB was used.

No practical difference was seen between the whites obtained on samples 1 and 1a or on 2 and 2a, respectively, where the same bleaching agent was used. Nor could it be seen that the fumigation had made the cotton either more easy to dye or more difficult to dye with direct or basic dyes.

MERCERIZING OF YARNS.

Samples of yarn made of each of the above four cottons, namely, 1, 1a, 2, and 2a, were mercerized by commercial methods at one of the mills in New Bedford, Mass., and these samples were subsequently tested for their tensile strength and degree of mercerization. In Table VIII the results of the average number of the yarn and tensile strengths,¹ ascertained before and after mercerization, are shown.

TABLE VIII.—*Tensile-strength tests of natural gray and mercerized yarns.*

Sample.	Natural gray.			Mercerized.		
	No. of yarn.	Strength in pounds per skein of 60 yards.	Strength in ounces per single thread.	No. of yarn.	Strength in pounds per skein of 60 yards.	Strength in ounces per single thread.
1.....	20.84	58.6	13.8	22.0	70.0	20.2
1a.....	20.84	59.9	13.9	22.0	71.2	21.0
2.....	30.5	56.0	15.0	30.7	66.0	19.9
2a.....	30.5	56.5	15.3	30.7	68.1	20.2

¹ See footnote, p. 6.

From Table VIII it will be seen that the gain in tensile strength due to mercerization is a trifle greater for the nonfumigated than for the fumigated cotton.

The tests for the degree of mercerization were made by dyeing samples of the fumigated and nonfumigated mercerized yarns in 1 per cent benzo purpurin 4 B, 10 per cent salt, 1 per cent soluble oil, 30 minutes at 160°, volume of bath equal to 100 times the weight of goods treated. The same weight samples of mercerized Egyptian yarn were dyed in the same bath after dyeing the fumigated and nonfumigated samples. These exhaust skeins furnished a means of measuring the degree of mercerization, for the better mercerized samples absorb more dyestuff and consequently leave less in the dye bath. In order to ascertain more accurately the degree of mercerization, a sheet of samples was prepared by dyeing mercerized Egyptian cotton with the percentages of dyestuffs shown in Table IX. Salt and soluble oil was used as in method given above, benzo purpurin 4 B being used as the dyestuff.

TABLE IX.—*A set of color standards.*

Standard No.....	1	2	3	4	5	6	7	8	9
Dye, per cent.....	5	4.5	4	3.5	3	2.5	2	1.5	1
Salt, per cent.....	20	20	20	20	20	20	10	10	10
Soluble oil, per cent.....	2	2	2	2	2	2	1	1	1

Standard No.....	10	11	12	13	14	15	16	17	18
Dye, per cent.....	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Salt, per cent.....	10	10	10	10	10	10	10	10	10
Soluble oil, per cent.....	1	1	1	1	1	1	1	1	1

Standard No.....	19	20	21	22	23	24	25	26	27
Dye, per cent.....	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01
Salt, per cent.....	10	10	10	10	10	10	10	10	10
Soluble oil, per cent.....	1	1	1	1	1	1	1	1	1

The samples of colored yarns obtained by dyeing in the exhaust bath were matched against the standards, and it was found that cotton No. 2a (nonfumigated 1½-inch Egyptian cotton) dyed a lighter shade, indicating a greater degree of mercerization than cotton No. 2 (fumigated 1½-inch Egyptian cotton). But results from lots 1 and 1a fumigated and nonfumigated, respectively, were practically identical.

CONCLUSION.

The results of these tests indicate that the fumigation of cotton with hydrocyanic-acid gas does not affect, to any material extent, the percentages of waste, spinning qualities, tensile strength, bleaching, dyeing, or mercerizing properties of the cotton.

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CARRYING CAPACITY OF GRAZING RANGES IN SOUTHERN ARIZONA.

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INTRODUCTION.

This bulletin presents the results of several years' experimentation and measurements leading to the determination of the carrying capacity of certain kinds of stock ranges in southern Arizona. The climatic and soil conditions under which the experiments have been carried on are those of the lower foothills and the sloping belt of grassland 8 or 10 miles wide which surround all the mountains of that region. The altitudinal variations are between 2,800 and 5,500 feet. All the area studied has been under control and observation for 11 years. Forty-nine sections which were badly run down by overstocking at the beginning of the study have been under a condition of complete rest from stock. Approximately nine additional sections (the most productive part of the area) have been grazed according to the judgment of four men who are acquainted with the region. Three of these men have been in the business of raising cattle; the fourth has had a few head of horses and burros in his pastures. The policy of each of the cattle raisers has been to stock his area as heavily as it would bear, allowing a small margin for slow improvement. The nicety of adjustment of the various factors involved in such a plan has depended upon each man's judgment of what was the best thing to do under all circumstances. By this arrangement the pastured area inside the fence has been subjected

to as nearly the same treatment as the adjacent unfenced range received as was possible under the circumstances. When these experiments were begun in 1903 the problems which presented themselves for solution were as follows:¹

(1) To demonstrate that under proper treatment run-down and overstocked ranges will recover, a statement of fact that was very much doubted by stockmen when the experiments were begun.

(2) To ascertain how long a time is necessary to get appreciable and complete recovery, and what methods of management will produce such results.

(3) To carry on reseeding and introduction experiments in the hope of increasing the total quantity of feed.

(4) To measure as accurately as possible the carrying capacity of a known representative area.

Results have already been published² relating to the first three of these questions. The present bulletin presents the data on carrying capacity which have been obtained so far. The methods of making collections originally established³ have been continued. Hay-cutting operations have been carried on for five years, and records of the number of "animal-days" feed⁴ used on measured areas of the reserve have been obtained by recording the number of stock on given areas for a period of seven years. From the hay-cutting records and the estimates based upon the collections an estimate of the carrying capacity is made, and this is compared with the actual results obtained from the pasturing records. Some additional miscellaneous observations relating to the project are included.

The generalizations presented here apply strictly to the area indicated on the map. They could be applied without modification to exactly similar localities and conditions. They doubtless present a statement of conditions closely similar to those on many other parts of the southwestern arid grazing land; they will be usable with but slight modification over most of southern Arizona, and to some extent in New Mexico and western Texas.

Three maps of the area studied are given for the better understanding of the region. One of these (fig. 1) presents the main relief features of the reserve, being based upon the Patagonia quadrangle of the United States Geological Survey contour map of the Santa Rita Mountain region. Another is an outline map (fig. 2) that shows where collections of material were made. The small letters (without accent) refer to the spring collections made in the years 1903 to 1908, inclusive. The accented small letters refer to the

¹ See Bureau of Plant Industry Bulletin 67, preface.

² See Bureau of Plant Industry Bulletins 67, 117, and 177.

³ See Bureau of Plant Industry Bulletin 67, p. 24 et seq.

⁴ As used in this bulletin, an "animal-day's" feed equals the feed necessary for one mature animal, cow, steer, bull, horse, or burro, for one day. Calves or colts when six months old are counted as mature animals, but are not counted at all before that time.

fall collections of the same years. Figures without circles show the location of spring collections and those in circles show the locations at which fall collections were made during the years 1912 to 1914, inclusive.

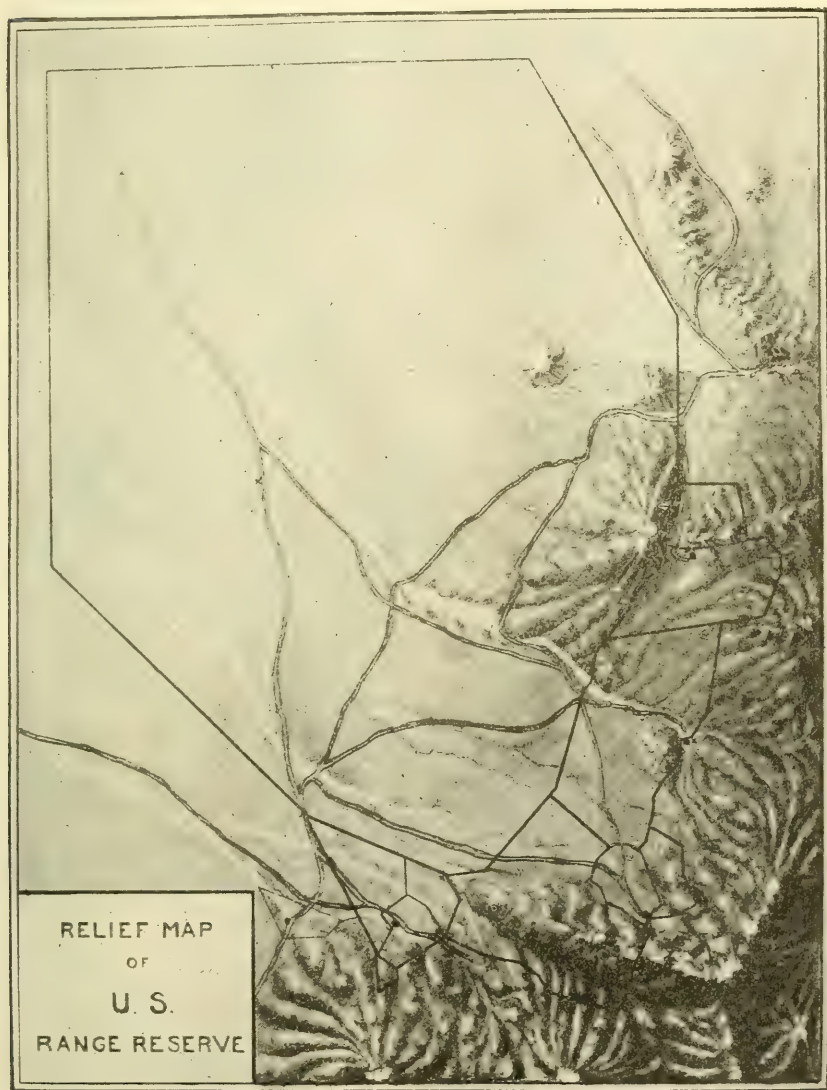


FIG. 1.—Relief map of the Santa Rita Range Reserve, Ariz., and some of the territory immediately surrounding it.

The plant-distribution map (fig. 3) is designed to put on record an approximation to the present distribution of the principal groups or associations of forage plants upon the reserve. Its use will be appreciated in the future study of the reserve if different adjust-

ments of the plant associations take place as the result of any particular kind of treatment. It does not rest upon accurate surveys, but is the best approximation which could be compiled by continued ob-

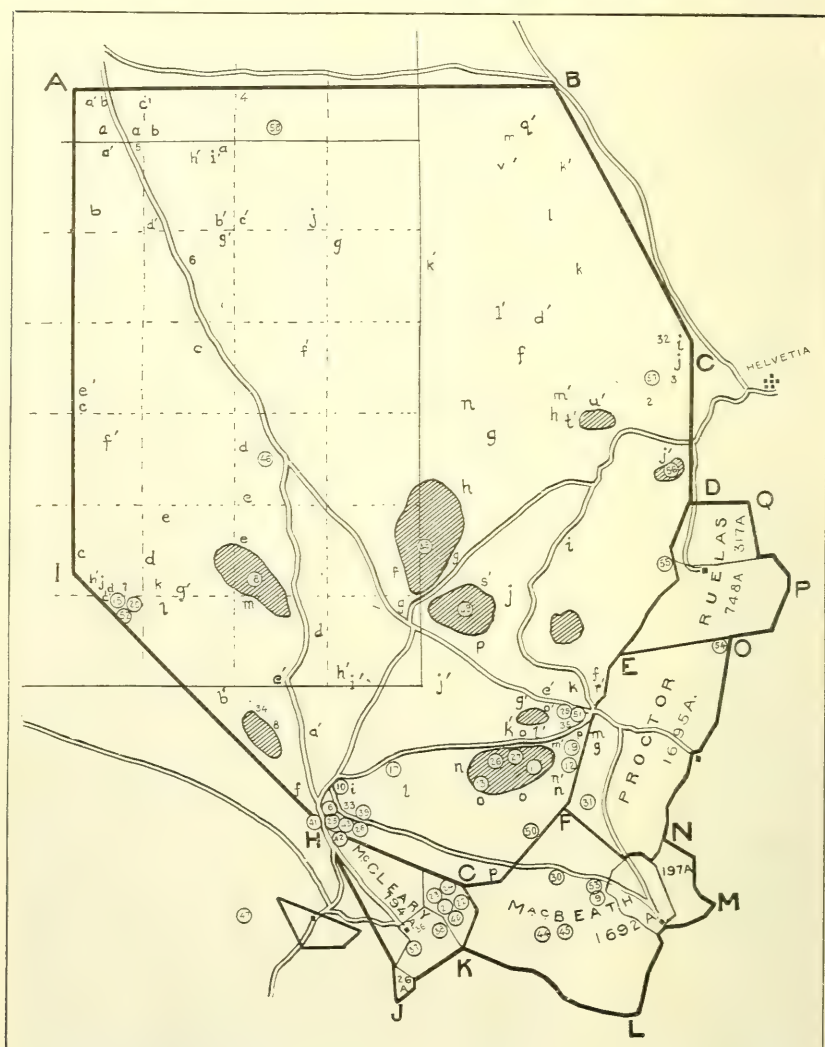


FIG. 2.—Outline map of the Santa Rita Range Reserve, Ariz., showing where quadrat collections have been made and where hay has been cut. The small letters refer to collections made from 1903 to 1908, inclusive, the unaccented letters indicating spring and the accented letters fall collections. Likewise, the small figures refer to collections made from 1912 to 1914, inclusive, the figures without circles indicating collections made in the spring and figures in circles fall collections. The shaded areas show where hay has been cut. The capital letters are introduced for convenience in reference.

servations and study made while riding over the reserve in all directions twice a year for the past three years. It is not a strictly ecological map, though some of its areas approximate the plant zones of the region. There is no doubt that the natural distribution

areas of certain species, and probably of the associations, had been much displaced by the previous grazing conditions to which the

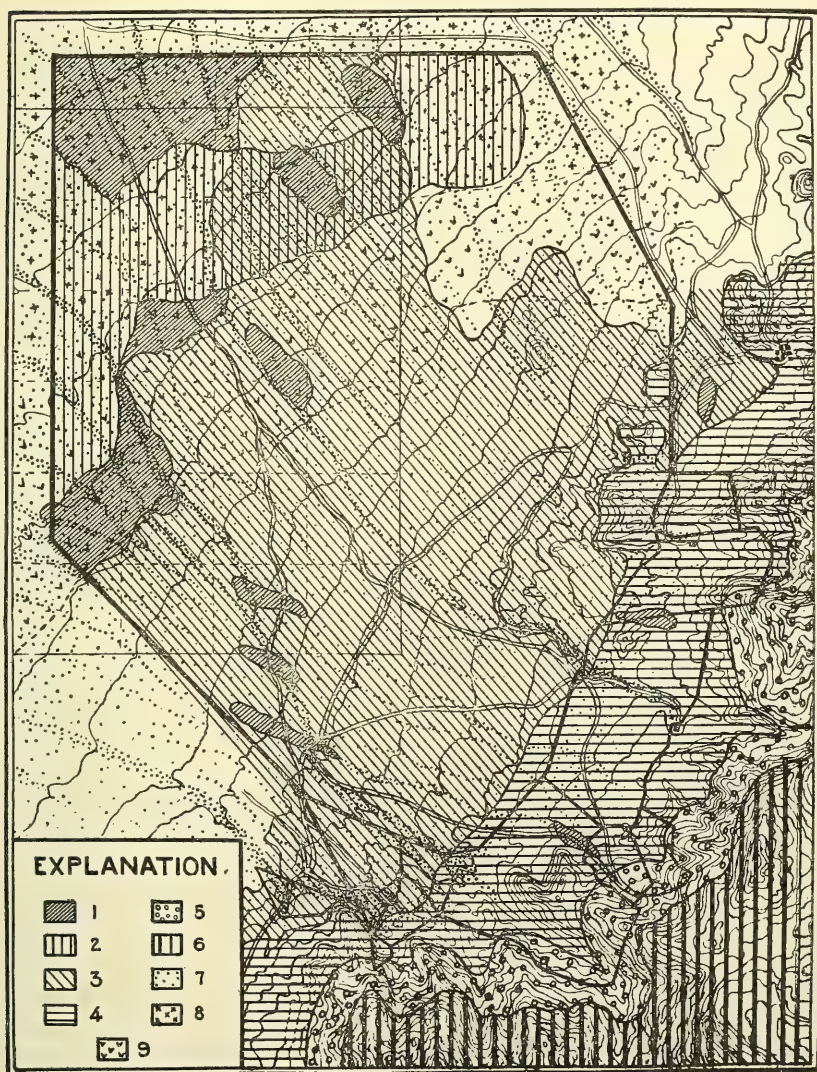


FIG. 3.—Map of the Santa Rita Range Reserve, Ariz., showing the present distribution of the principal forage-plant associations: No. 1, The six-weeks-grass association. No. 2, The black-grama association. No. 3, The crowfoot-grama association. No. 4, The needle-grass association. No. 5, The oak belt. No. 6, The forested area. Those parts of the reserve upon which the mesquite (*Prosopis velutina*), the cat's-claw (*Acacia greggii*), and other shrubs or low trees occur, more or less abundantly, are indicated by dots (No. 7) on the map. In the same way, the crosses (No. 8) and the check marks (No. 9) show where the tree cactus (*Opuntia spinosior*) and the cholla (*Opuntia fulgida*) are important members of the plant associations (Pl. I, fig. 2).

region had been subjected, and that under the protection of the fence these plants have been and are still readjusting themselves to the normal ecologic conditions. Maps of this kind made at various in-

tervals should show something of the changes taking place, and the more accurately they can be drawn the more valuable will be the information obtainable from such a series.

CLIMATIC CONDITIONS.

The importance of those factors known as climatic conditions do not need to be argued, especially in relation to the arid grazing lands, where the whole crop of forage is so patently dependent upon them. The peculiarities of the seasons upon the Santa Rita Range Reserve have already been discussed by Dr. Griffiths,¹ who calls particular attention to the two growing seasons and shows that they depend upon the amount and distribution of rainfall.

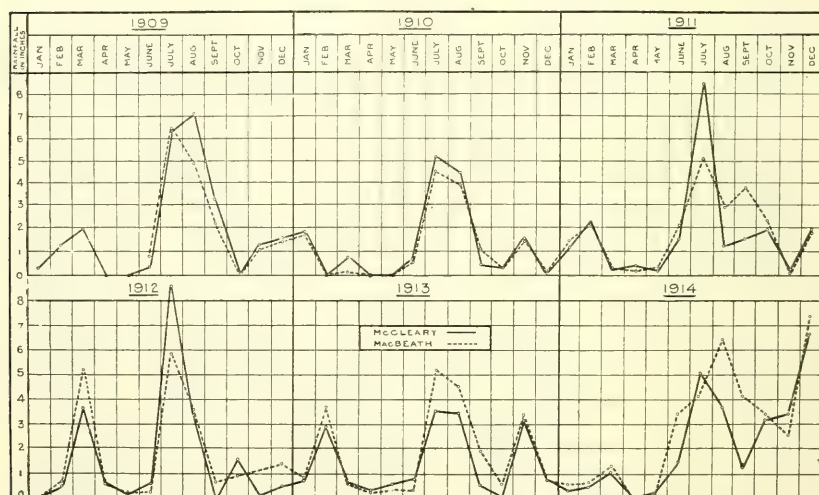


FIG. 4.—Curves showing the variations in the total monthly precipitation at two stations on the Santa Rita Range Reserve, Ariz., through a period of six years.

The spring growing season is dependent upon the rain of the previous fall and winter, taken with what may fall in the spring proper. In April and May, and in at least a part, if not all, of June, there usually occurs a period of dry weather, during which most growth ceases and the spring annuals dry up. July, August, September, and sometimes part of October constitute the summer growing season, since it is during this period that the greater part of the rain falls and, the temperature being high, rapid growth occurs.

Records of the rainfall by months at McCleary's house have been kept since July 1, 1901. In June of 1909 a rain gauge was placed at MacBeath's house and the records from both these stations are given in Table I. A comparison of the two records by months is shown in the diagram (fig. 4).

¹ See Bureau of Plant Industry Bulletin 67, pp. 38-44.

TABLE I.—*Precipitation, in inches, at MacBeath's place and at McCleary's place, Santa Rita Range Reserve, Ariz., by months, 1909 to 1914, inclusive.*¹

MACBEATH'S PLACE.

Month.	1909	1910	1911	1912	1913	1914	Average,
January.....		1.69	1.40	0	0.93	0.60	0.92
February.....		0	2.03	.70	3.71	.75	1.44
March.....		.13	.26	5.18	.60	1.29	1.49
April.....		0	.18	.62	.23	0	.20
May.....		0	.38	.24	.40	.05	.21
June.....	0.85	.57	2.04	.27	.42	3.44	1.27
July.....	6.45	4.64	5.05	5.89	5.15	4.09	5.21
August.....	4.90	3.94	2.96	3.69	4.58	6.48	4.43
September.....	2.17	1.02	3.79	.70	1.94	4.08	2.28
October.....	0	.26	2.27	.99	.58	3.45	1.29
November.....	1.03	1.43	.04	0	3.33	2.56	1.90
December.....	1.36	.18	1.83	1.38	.82	7.39	2.16
Total.....		13.86	22.23	19.66	22.69	34.18	22.80

MCCLEARY'S PLACE.

	1909	1910	1911	1912	1913	1914	Average,
January.....	0.28	1.71	1.15	0	0.86	0.37	0.73
February.....	1.22	0	2.06	.58	2.98	.55	1.23
March.....	1.98	.81	.21	3.64	.62	1.09	1.39
April.....	0	0	.38	.65	.30	0	.22
May.....	0	0	.16	.20	.60	.08	.17
June.....	.30	.69	1.51	.56	.86	1.55	.91
July.....	6.40	5.10	8.40	8.63	3.64	5.03	6.20
August.....	7.03	4.41	1.17	3.49	3.51	3.74	3.89
September.....	3.21	.51	1.53	0	.67	1.21	1.19
October.....	0	.26	1.95	1.55	.02	3.11	1.15
November.....	1.12	1.55	.10	.10	3.11	3.40	1.56
December.....	1.40	.16	1.91	.48	.83	6.67	1.91
Total.....	22.94	15.20	20.56	19.88	18.00	26.80	20.55

¹ The observations recorded in this table were not made by regular United States Weather Bureau observers, though United States standard rain gauges were used. The readings were made with the standard measuring stick between 6 and 8 o'clock the morning after the rainfall occurred.

A study of these data shows that the average annual rainfall at MacBeath's (elevation about 5,000 feet) has been about 11 per cent greater for $5\frac{1}{2}$ years than at McCleary's (elevation about 4,000 feet), although the two stations are only about 3 miles apart on a straight line. They also show that the precipitation by months at McCleary's has been greater than at MacBeath's 26 out of the 66 months of the record.

For 1914 records were obtained at Mr. Robinson's camp (elevation about 4,500 feet) that are valuable for comparison with the others. Records for the last four months of 1914 were also made at Rosemont (elevation, 5,000 feet), 9 miles away as the crow flies, on the other side of the mountain range. It is impossible to present the daily records for these different stations in any sort of diagram that could be printed here, but a study of the records by days brings out one or two generalizations which are of some importance.

The first and most noticeable of these is the exceedingly restricted areas over which the rain falls at any one time. It must be understood that the most of the rain that falls in the region, particularly that of the so-called rainy season of summer, comes as local showers

covering small areas. This general truth may be recognized any summer, since it is often possible to see several separate showers falling at the same time in different directions from the observer.

Another fact brought out by a study of the records is that, while the showers do not occur at the same time at the three stations, rain at one station is usually preceded or followed by rain at the others. In other words, while each shower is small in extent of area covered, the single shower is only one of many occurring in a period of time extending over several days, which ultimately fall on most of the area. The daily differences disappear when the monthly and annual totals are made up, and other facts appear when these are plotted as curves. By this method the seasonal character of the distribution for each station is shown, and the averages for a period of years bring out the difference due to elevation.

One further consideration must be kept in mind. The stations at which rainfall records have been obtained are all in the edge of the mountains, at elevations of 4,000 to 5,000 feet. The records obtained at MacBeath's are about typical for the upper edge of the pastured areas; those from McCleary's for the lower edge, which is at the same time the upper edge of the recovery pasture. The lowest part of the recovery pasture is about 8 miles from the mountains, toward the middle of a wide bolson, or basin, and 1,000 feet lower in altitude. It therefore does not get the same amount of rainfall as that received at McCleary's, the nearest station. The only other station from which we have records bearing upon the problem is that of Tucson, 30-odd miles to the north and 600 feet still lower down. What may be called the normal annual precipitation at McCleary's is about 17 or 18 inches. This amount falls upon about 16 sections (28 per cent) of the reserve. About 10 sections (17 per cent) of the reserve, most of which is pastured, gets about a 20-inch normal rainfall. Assuming that it is fair to interpolate between the normals for McCleary's and Tucson on the basis of altitude, we have 32 sections (55 per cent) of the reserve receiving a normal of something like 12 to 14 inches. Besides these general differences in precipitation, we have an increasing degree of annual fluctuation in amount of precipitation; a greater amount of evaporation, due to increased temperature; poorer soil protection by vegetation; and longer periods of desiccation as we go from the mountains toward the middle of the basin. All these factors are registered in the vegetation, both in its character and its quantity, and the summation of these differences affects most profoundly the carrying capacity of this region for stock. Snow in quantity, depending largely upon the elevation, occurs at rather rare intervals in the winter, but lies on the ground for only a short time. One of the heaviest snows for a number of years is shown in Plate I, figure 1.



FIG. 1.—VIEW IN THE OAK BELT ON THE SANTA RITA RANGE RESERVE, SHOWING AN OCCASIONAL WINTER CONDITION.

Such snows are quite infrequent and last but a few days at most.



FIG. 2.—A DENSE STAND OF CHOLLAS (*OPUNTIA FULGIDA*) IN THE NORTHEASTERN PART OF THE RESERVE



FIG. 1.—A VERY DENSE STAND OF THE SIX-WEEKS GRASSES ON THE SANTA RITA RANGE RESERVE.



FIG. 2.—THE GENERAL APPEARANCE OF THE BEST OF THE BLACK GRAMA ASSOCIATION ON THE RESERVE.

CHARACTER AND DISTRIBUTION OF FORAGE.

Attention has already been directed to the variation in the average annual precipitation that occurs on different parts of the Santa Rita Range Reserve and its relation to the forage crop produced.

Protection from stock has allowed the plants of the greater part of the range to assume something like a normal adjustment among themselves and to the climatic conditions, and this adjustment has resulted in certain tolerably well-marked groupings of species of plants that cover areas of considerable size. Such assemblages of species, which have similar climatic and soil requirements and live together in a given area, are here called plant associations, and five of the principal associations are named. An attempt to map somewhat roughly the area covered by each, in order that the relative importance and productivity of each may be readily grasped, is shown in figure 3.

A more detailed description of these associations follows, in which the writer has attempted to give some idea of the character of the forage which they produce. Each association (except one) is designated by the name of its most important and most abundant grass. This species is not always the most noticeable or largest plant of its distribution area, but is the most important forage plant.

Plant associations selected upon this economic basis can hardly be expected to be the typical ecologic associations of the region, and a map setting forth these ideas is not an ecological map in the generally accepted sense. As a matter of fact, the major part of the attention is directed to the subdivisions of the grass zone of the region, and the areas represented are not of equal rank from an ecological standpoint. However, the economic consideration is of first importance here, and with these explanations the descriptions of what had better be called associations of forage plants may be taken up.

THE SIX-WEEKS-GRASS ASSOCIATION.

The dominant species of the six-weeks-grass association (No. 1 in fig. 3) are *Aristida bromoides* and *Bouteloua aristidoides*, short-season annuals, as is indicated by the common name. (Pl. II, fig. 1.) A grass that is usually referred to under the first name, but may be another species, makes a growth during the late spring before the early-summer dry spell, if there be sufficient spring rainfall, though this growth is often quite scanty. During the summer-growing period these grasses make surprisingly rapid growth and are very numerous on most of the bare ground at nearly any level on the reserve. They grow as thickly as they can stand, the stronger crowding out the weak, and all mature seed whether the season or the conditions be such as will produce a growth of a foot or only a few

inches. The certainty of producing a crop of seeds and the ability of these seeds to endure desiccation and to plant themselves are factors which probably account for the distribution of these grasses. They are easily crowded out by even the least aggressive of the perennials, yet they occur as scattered individuals among nearly all the other grasses almost any season, though this habit is not so well shown by the *Bouteloua* as by the *Aristida*. Wherever, for any reason, the perennial grasses are killed out these grasses occupy the ground for the short summer growing season.

The six-weeks grasses now occupy at least six or seven sections of the reserve as an almost pure stand, while they form a very important part of the assemblage here referred to as the black-grama association (No. 2 in fig. 3) and the crowfoot-grama association (No. 3 in fig. 3), especially along the boundaries of these areas. It is difficult to say definitely in many places just where the six-weeks grasses cease to dominate the association, and there is certainly no such well-marked boundary line between this association and those adjacent to it as is suggested by the more or less arbitrary divisions made in this bulletin. When the range reserve was first inclosed, this association was of greater extent than any other grass association in the reserve. It has been replaced primarily by the crowfoot-grama association from above, but the black-grama association has also crowded in from below, and the latter, while much slower in its encroachments and much more easily checked by grazing, may in the end dominate both the others if the area be protected for a sufficient time, especially if fire be prevented.

Considered as a forage crop and from the standpoint of their economic importance, the grasses of this association are not of great value. They produce a light crop of forage; the crop lasts but a short time and loses feeding value rapidly, being almost valueless by the middle of the winter; and for some reason (probably because the plants pull up easily and thus get dirt in the animals' mouths) stock do not eat them while at their best, unless there is nothing else to be had. However, the growth of spring annuals is usually heaviest on this area, and they add considerable good feed to the total annual crop.

THE BLACK-GRAMA ASSOCIATION.

Across the northwest corner of the reserve and extending along much of the west side is an area in which the most conspicuous grass is what is called "black grama" in this region (No. 2 in fig. 3). The grass in question is not a member of the genus *Bouteloua*, which contains what are usually called gramas, its scientific name being *Muhlenbergia porteri* (Pl. II, fig. 2). Its importance in the early days of the stock business in this region has been discussed by

Griffiths¹ and Thornber². Certain characteristics of this grass need further emphasis, however, since by virtue of them it offers possibilities not shown by many other grasses of the region. It endures great extremes of temperature and dryness; it grows upon some of the poorest and driest of the gravelly mesa soils; it occurs at altitudes ranging from about 2,000 to over 4,000 feet; it is excellent feed; its stems are perennial and die back but a short way at the tip each winter, thus furnishing feed at any time in the year. These are its good points. It must be remembered that its growth is very slow, dependent entirely upon the water supply of a very dry region; that its seeding habits are poor, and that conditions for germination are poor even when viable seeds are produced; that it is easy to overestimate the carrying capacity of a previously unstocked range of this kind of grass, because the growth present is that of several seasons. These are the bad points. This grass usually occurs under the bushes and may be found sparsely scattered over all the mesa country in such protection. It certainly will not bear any degree of overstocking, but it is at least doubtful if students of grazing conditions (the writer included) are warranted in treating this grass as not worthy of much consideration, as has been very largely their habit hitherto.

The way that this grass (probably the best feed of its distribution area) has managed to persist in a region which has been thoroughly denuded of everything in the way of stock feed is of itself noteworthy. And observations in the reserve have demonstrated clearly that under protection from animals it is capable of dominating areas where it was thought to be almost a negligible factor. When the fence was first built it was hard to find any large plants of this species,³ and they were always under bushes. After 11 years of protection it is fairly common all over the reserve below the 3,800-foot contour, and, while the old plants are more apt to occur in the bushes, their presence there is not universal nor due to the necessity of shade or protection, but probably because such situations are more favorable for the germination of the seeds. Within the past four years, since seed plants have become tolerably numerous, the species has spread quite rapidly in the northwestern quarter of the reserve and has put a considerable crop of good feed on an area that previously produced a very small crop of poor feed. And there is little doubt that under protection this plant will come to dominate much of the reserve, especially that part of it where the other perennial grasses grow but poorly. The spread and development of this plant under protection is strongly corroborative of the claims made for it by the

¹ See Bureau of Plant Industry Bulletin 177, p. 17.

² See Arizona Experiment Station Bulletin 65, p. 279.

³ See Bureau of Plant Industry Bulletin 177, Pl. IV, fig. 1.

elder stockmen of the region, claims that have seemed to the writer at times very hard to believe and very easy to discount at a high rate.

It is not intended to imply by what has been said that the black grama is the dominant plant of the area here called by its name. The area in question is largely covered by large shrubs, such as mesquite, cat's-claw, palo verde, and cacti of various kinds. Besides these, there are the spring and summer annuals occurring in greater or less profusion according to the season. The writer has not seen the abundance of *Atriplex elegans* mentioned by Griffiths¹ in the region, nor some of the other species referred to, but the amount of grass in that region has increased considerably. Besides the annuals, crow-foot grama has spread as far north as the north fence and is pushing westward.

Along the west fence, on the broken, gravelly ridges, considerable wire grama (*Bouteloua eriopoda*), some *Dasychloa pulchella*, and less six-weeks grass occur associated with the black grama. The wire grama is very much like the black grama in its habits as a plant and its value as forage, and the treatment which would suit the one would satisfy the other. The two together, if given a chance, would doubtless put a crop of forage on much of southeastern Arizona that is now quite barren, but a number of years of protection would be necessary to produce this result. This grass association now furnishes the most of the available forage over approximately seven sections of the reserve, an area on which it was very unimportant 11 years ago.

THE CROWFOOT-GRAMA ASSOCIATION.

The crowfoot-grama association is the most important association now occupying any part of the area studied, mainly because it occupies more than half of it (No. 3 in fig. 3). It now covers about 31 of the 58 sections under fence and is still slowly extending its borders west and north. It is also important as furnishing an amount of forage that is about an average of the production of all the different forage-producing belts or zones of the region. It thus becomes an approximate measuring rod for the estimation of carrying capacity for the region.

The association consists mainly of grasses, of which crowfoot grama (*Bouteloua rothrockii*) is the most conspicuous and certainly the most abundant, though by no means the only one (Pl. III, fig. 1). At all levels except the very lowest may be found more or less of *Bouteloua filiformis*, which is also an important component of the needle-grass association; and three of the needle grasses (*Aristida divaricata*, *A. scabra*, and *A. californica*) also occur in greater or less abundance in this association. Along the upper side of the

¹ See Bureau of Plant Industry Bulletin 67, p. 26, plats A and B; p. 28, plats A', B', and C'.

area and extending into the needle-grass area, Texas curly-mesquite grass (*Hilaria cenchroides*) and *Heteropogon contortus* are common, forming almost pure stands of small extent (Pl. III, fig. 2). The wire grama (*Bouteloua eriopoda*) also contributes considerable to the forage crop of this association, but has its own distribution limits; it frequently covers areas of a few square yards to the complete exclusion of everything else. Besides the grasses, there are various other herbaceous annuals and perennials that appear either in the spring or summer and add to the total crop. There is a scattering growth of shrubs like mesquite, cat's-claw, desert willow, etc., over most of the crowfoot grama area, thickest along the arroyos and toward the west and north, but usually not heavy enough to in any way affect the growth of the grass. These add an amount of feed of which we have no measurements, because they were not obtainable with any degree of accuracy. Prickly pears and chollas are quite abundant in places, but a heavy crop of grass tends to kill them out, probably because of occasional fires which sweep the grassed area.

Earlier reports have shown the rate at which this association took possession of the upper part of the reserve, and photographs show very clearly how well the grass has grown. Pictures recently taken indicate that the grass is even thicker and larger now, and observations show very definitely that within five years the boundary of the crowfoot-grama area has moved westward more than a mile at the south end of the reserve, and about 2 miles to the northwest along the Tucson road. In the north-central part of the reserve the characteristic plants of this association are now more numerous than those of the six-weeks-grass association clear to the north fence, though much black grama, six-weeks grass, bushes, and cacti occur here, and there is also considerable bare ground in the region. What will ultimately dominate does not yet appear, but the important factor is the aggressiveness of both the black-grama and the crowfoot-grama grasses. It has taken a long time for this improvement and spread to show, because there were few seed plants to start with; and germination conditions are so severe that only a few new plants were established each year, or at even longer intervals.

THE NEEDLE-GRASS ASSOCIATION.

The needle-grass association is the assemblage of plants which forms the grass belt along the foothills, covering approximately nine sections of the area under fence (No. 4 in fig. 3). It is not clearly marked off from the crowfoot-grama association, there being more or less overlapping both ways. The line on the map which separates the two areas is as nearly where the crowfoot grama ceases to be the most important grass and the needle grasses assume that im-

portance as the writer was able to locate it. It may be undesirable from some standpoints to try to separate these associations, but to do so has seemed to give a little clearer conception of the conditions existing on the reserve, even though the crowfoot grama will go higher and the needle grasses do go considerably lower and notwithstanding the fact that other grasses occur freely in both associations and seem to link the two.

The needle-grass association consists of a number of important perennial grasses, of which *Aristida divaricata* and what is probably *A. scabra* are the most abundant (Pl. IV, fig. 1), hence the name here suggested. The next most important grass is *Bouteloua filiformis*, which frequently makes up from one-fourth to one-third of the assemblage. Toward the upper limit of the belt this grass is apt to be replaced by *B. chondrosioides*. Hairy grama (*Bouteloua hirsuta*) also occurs on the rockier hills, and Texas curly mesquite (*Hilaria cenchroides*) is not uncommon at the lower side of the zone.

Wherever the needle-grass association is entirely killed out the six-weeks grasses and annuals first take the ground, and then the short-lived perennial gramas appear in abundance before the longer lived perennial *Aristidas* become established. As the greater part of this belt that is inclosed is grazed by cattle and horses, the various conditions mentioned may be found at different places in the different pastures. Wherever the stock congregate most the six-weeks grasses and annuals abound. Where this condition of local overgrazing is relieved some step in the sequence of complete replacement of the association occurs.

Additional perennial grasses in this association are Texan timothy (*Lycurus phleoides*), tall, or side-oats, grama (*Bouteloua curtipendula*), *Eragrostis lugens*, *Elionurus barbiculmis*, and *Trachypogon montufari*, while numerous spring and summer herbaceous annuals and perennials add considerable to the forage crop. The lower limit of these needle grasses is not the limit of the association, since they are common in patches in the crowfoot-grama association and follow down the dry watercourses, or arroyos, to the very lowest parts of the inclosed area. In many places in the crowfoot-grama association they may constitute as much as 25 per cent of the forage present on the ground. Whether or not they will gradually crowd downhill and finally replace the crowfoot-grama association remains to be seen, but at present the writer believes they require a little more water than the crowfoot grama and will hardly be able to entirely replace that association as it now exists on the reserve, no matter how long the area may be protected. No data are available relative to the crop of spring feed upon this area, but it is doubtless of no great importance except where overgrazing has occurred.

THE OAK BELT.

About one section of the land in the MacBeath inclosure lies in the zone of the oaks (No. 5 in fig. 3). The forage in this area is composed mainly of the grasses of the needle-grass association (No. 4 in fig. 3), with a diminution of the amount of perennial species of *Aristida* and an increase of *Bouteloua chondrosioides*, *B. hirsuta*, *Elionurus*, *Trachypogon*, and others. The oak trees are distinctive of the zone, and the young ones afford considerable feed as browse, as do a number of the other shrubs and some perennial herbs (Pl. IV, fig. 2). The precipitation of this belt is greater than that of any of the others, and there is no doubt that, including the browse and spring growth, the area produces more feed than the lower levels, though complete figures are not available to demonstrate how much more. This fact must be kept in mind in the comparison of the records of animal-days' feed produced on the MacBeath inclosure.

THE PLOWED AREAS.

In the summer of 1912 it was decided to plow areas of an acre in extent in different parts of the reserve and determine as far as possible the sequence and rate of the return of the plants after they had been completely killed out. The effects of the change in the soil conditions were also considered. Late in September, areas were selected, measured, and plowed. One acre was chosen in the best of the crowfoot-grama area near the south gate (at H, fig. 2), and another in the six-weeks grass area where rayless goldenrod (*Isocoma hartwegii*) was very abundant, near the southwest corner of the reserve (at I, fig. 2). Collections as nearly representative as possible were made on these areas (Nos. 15 and 16, fig. 2) before the plowing was done, and the hay on the acre (near H, fig. 2) was cut and weighed.¹ The plowing on the area (near I, fig. 2) was poorly done, so that the plants of *Isocoma* were not all killed, and it was plowed again more thoroughly and deeper (about 4 inches) in December, 1913. At this later date another acre was plowed near the gate (at H, fig. 2), the intention being to get a larger number of collections for comparison. Collections have been made on each of these plowed areas each year, and other collections have also been made on the unplowed land beside the plowed area near the gate. These collections (Nos. 16, 25, and 43, fig. 2) indicate the production of forage on the unplowed land, the average total production for the three years being approximately 1,018 pounds of herbage per acre, of which 601 pounds, or nearly 60 per cent, is grass. Of this grass 570 pounds, or 56 per cent of the total herbage, is perennial grass. Comparing these results with others derived from

¹ See record in Table IV, for 1912: Felix, 1 acre=750 pounds.

collections (Nos. 28 and 42, fig. 2) made on the area plowed in 1912 and those (Nos. 39 and 41, fig. 2) made on the area plowed in 1913 gives an average total production of 797 pounds per acre, of which 389 pounds, or less than 50 per cent, is grass, and of this grass 164 pounds, or slightly more than 25 per cent of the total herbage, is perennial grass. A spring collection on this area (No. 33, fig. 2) made the second spring after plowing shows no real spring plants at all and no grass growing. The plants collected were all small, green, and growing, or rather waiting for more water to continue their growth. They were all species that belong to the summer rather than the spring growth. On the unplowed ground near by the small spring annuals, *Plantago*, *Gilia*, *Caucalis*, *Filago*, etc., were very small and all dried up at this time and, except for a few *Gilia floccosa*, were none of them growing on the plowed land. The difference was doubtless due to the condition of moisture of the surface soil which existed at the time of germination, the amount of available moisture in the soil, and the depth of planting required by the different seeds. The grasses will almost certainly take possession of these plowed areas in a shorter time than they would on an overstocked range, since the plants all about the area will furnish plenty of seeds, and the soil's ability to catch and hold water has been increased considerably by the plowing. As the soil settles and grows more compact the smaller spring annuals may be expected to become abundant. The plowed area near the southwest corner (at I, fig. 2) produced a much smaller amount of available feed which was largely composed of annual grasses even before plowing. The average amount of feed as shown by the collections made in 1913 and 1914 is of the same order of magnitude as that of the unplowed ground, but has a smaller proportion of grass of any kind and almost no perennial grass. The rate at which this area will be invaded by the *Isocoma* will be of some importance. No seedlings of this species were found on the plowed land in September, 1914, though special search was made for them. There were numerous seeding plants in the vicinity and a few of them on the plowed area itself.

NATURE AND RATE OF THE RECOVERY.

A comparison of the condition of the fenced area as described by Griffiths at the time of its inclosure in 1903¹ with its condition in 1914, as given in this bulletin, brings out some interesting generalizations as to the nature and degree of recovery that may be expected upon overstocked and eaten-down ranges in this region when properly cared for. In 1903 the grasses were to be found in anything like a thick stand only as far north and west as a line con-

¹ See Bureau of Plant Industry Bulletin 67.



FIG. 1.—THE CROWFOOT GRAMA ASSOCIATION IN A TYPICAL FORM ON THE SANTA RITA RANGE RESERVE.



FIG. 2.—A PATCH OF *HETEROPOGON CONTORTUS* ON THE RESERVE, SHOWING THE HABIT, SIZE, AND DENSITY OF THIS GRASS AS IT GROWS IN THE CROWFOOT GRAMA ASSOCIATION.

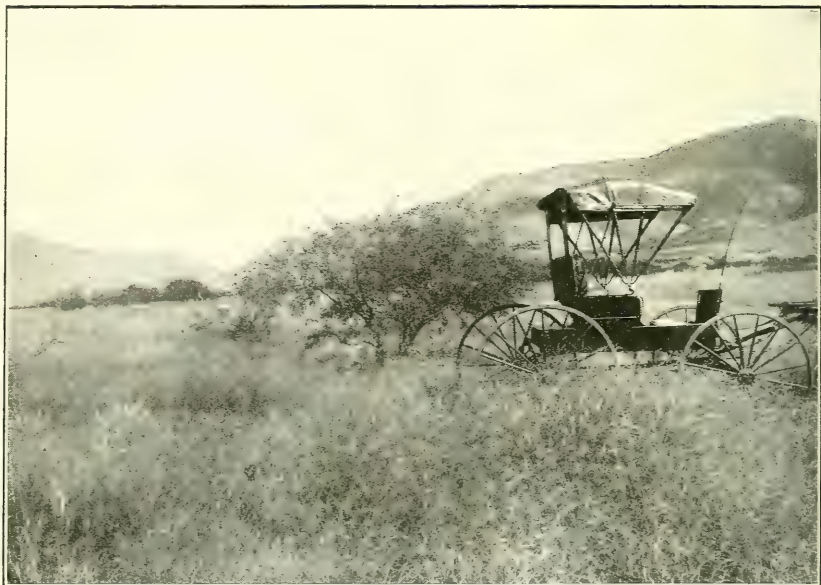


FIG. 1.—A CHARACTERISTIC DISPLAY OF THE NEEDLE GRASS ASSOCIATION UNDER COMPLETE PROTECTION ON THE SANTA RITA RANGE RESERVE.



FIG. 2.—GRAZING CONDITIONS IN THE OAK BELT ON THE RESERVE.

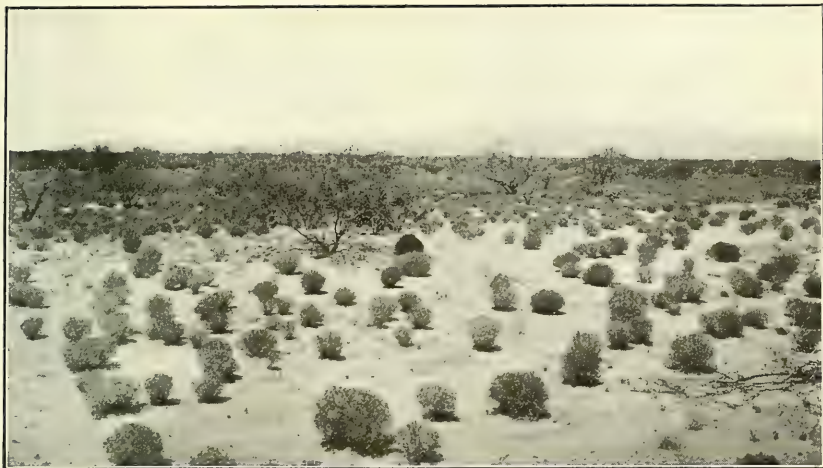


FIG. 1.—CONDITIONS IN THE SOUTHWEST CORNER OF THE SANTA RITA RANGE RESERVE IN 1903.

The rayless goldenrod is just beginning to occupy bare ground. (Compare with fig. 2.)



FIG. 2.—CONDITIONS IN THE SOUTHWEST CORNER OF THE RESERVE IN 1913.

The ground is almost completely covered with vegetation. Note the large amount of grass in the association; in 1914 a considerable part of the goldenrod was dead as the result of crowding by the grass. (Compare with fig. 1.)

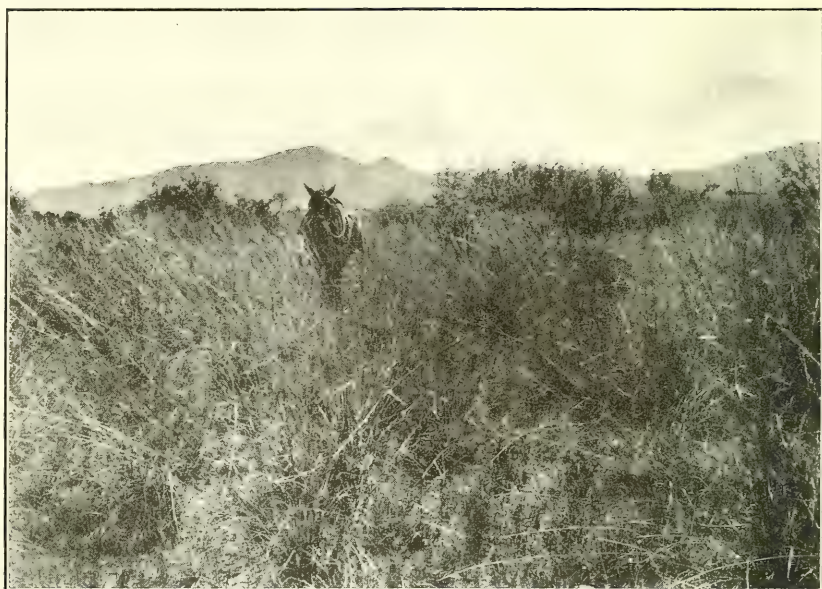


FIG. 1.—AN ALMOST PURE STAND OF DEER-GRASS (*EPICAMPES RIGENS*) ON THE SANDY SOIL OF ONE OF THE LARGER ARROYOS ON THE SANTA RITA RANGE RESERVE.

This grass is common in such situations.

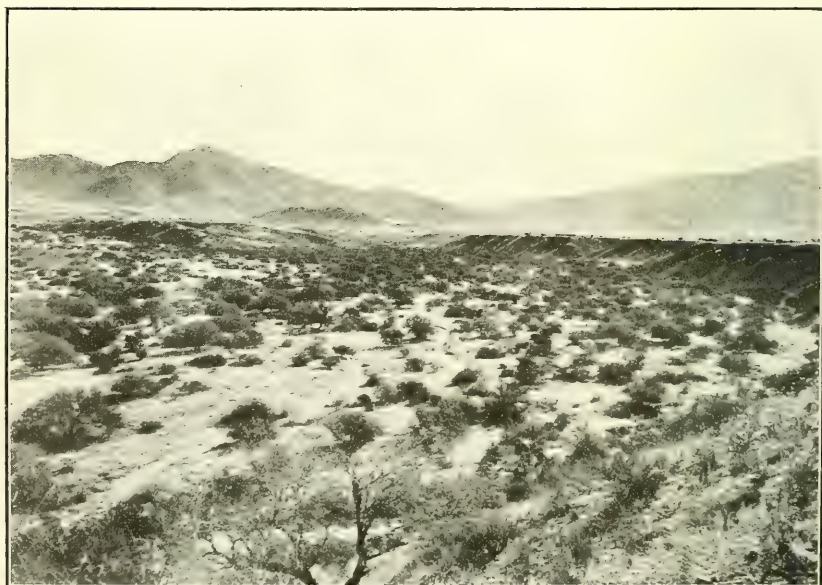


FIG. 2.—AN ARROYO FILLED WITH MESQUITE, CAT'S-CLAW, AND OTHER SHRUBS ON THE RESERVE.

necting C and I on the map (fig. 2). It was difficult to find any black grama in the field.¹ In 1914 the perennial grasses had pushed northwestward along the Tucson road at least $1\frac{1}{2}$ miles, if not 2 miles, farther than they extended about five years before, and were established about 1 mile farther west along the south side of the field. The crowfoot grama has reached the north fence, not as a pure stand, but as the most important element of a well-developed though not yet complete grass association. In this same area the black grama is now abundant and spreading. Along the west fence is an area where the black and wire gramas are becoming abundant and important. In the southwest corner is an area of a section or more where rayless goldenrod (*Isocoma hartwegii*) showed a scattering growth in 1903.² This same area is now thickly covered with large mature plants of this species (Pl. V, figs. 1 and 2), a large number of which are dying, probably as the result of the encroachment of the grasses which are gradually taking possession of the area.³ The rayless goldenrod is of no value as a forage plant and it is customary to think and speak of it as a range weed and a nuisance. But it certainly protects the soil from erosion, retards run-off, and furnishes conditions favorable to the germination of the grass seeds. The grasses will probably eventually crowd it out.

One of the most noticeable features of the grass-covered area of the reserve is the prevalence of spots a few square yards in extent covered by an almost pure stand of some long-lived perennial grass. This habit is more or less characteristic of the black grama (*Muhlenbergia porteri*), but especially true of the wire grama (*Bouteloua eriopoda*), and of a coarse grass called *Heteropogon contortus* (Pl. III, fig. 2). The two first named are valuable forage plants; the last is usually considered undesirable.

Measurements show what is very plain to simple observation, that the *Heteropogon* puts a relatively large crop of feed on the ground. But this feed is almost valueless while green because the animals do not like it, and the grass is usually avoided in the hay cutting because of the large, sharp seeds that hurt the mouths of the animals. In 1914 about 100 pounds of this grass was cut and cured just before it commenced to seed. It made a very good quality of hay, which was eaten by one of the work horses with relish and in preference to old grama hay of the previous season. It would seem that this grass may have a possibility as a hay crop, if cut at the proper time. It is a long-lived, strong-rooted perennial that spreads by rootstocks and grows about 2 feet high.

¹ See Bureau of Plant Industry Bulletin 177, Pl. IV, fig. 1, photographed in November, 1902.

² See Bureau of Plant Industry Bulletin 177, Pl. IV, fig. 2, photographed in June, 1903.

³ The comparative data here given are supported by the testimony of Mr. W. B. McCleary, who has known this range for the past 15 years and who drove over a large part of it with the writer in September, 1914, for the purpose of making comparisons.

Along the arroyos several grasses have taken possession, and the crop of feed they put on the margins of these dry watercourses is probably sufficient to render this broken land as productive of feed as the smoother areas (Pl. VI, fig. 1).

There is no doubt that the prediction made by Griffiths, that the mesquites and other shrubs would increase in size and number, is slowly coming true within the protected area (Pl. VI, fig. 2, and Pl. VIII, fig. 1). The only retardation they have received has been from the occasional fires, some of which have been severe enough to completely kill plants 10 to 12 feet high, though usually only the smaller bushes are killed back to the ground.

Along with the information relative to the general character of the changes taking place on a protected area, some data have been obtained as to the rate at which these changes take place.

The spring annuals and the six-weeks grasses occupy the bare land at once wherever there is sufficient rainfall. The recovery of the short-lived perennials was quite well advanced on this reserve after about three years' complete protection, and the area covered by them has certainly doubled in size in seven years' time. It has taken at least seven or eight years to bring about a condition favorable for the increase of the black grama; and this increase will doubtless continue for another 10 years before reaching its maximum. Yet much of the land, where this plant normally grows, would doubtless produce a crop of this grass where practically no forage grows now if it were given a period of complete rest for a few years and very light stocking for a number of years more. On the areas that have been carrying stock the recovery has been much less rapid, though very noticeable improvement has occurred.

CARRYING CAPACITY.

The method of making quadrat measurements, established by Griffiths,¹ has been continued by the writer since he has been connected with the work. The detailed reports of these records for the years 1903 to 1908 and 1912 to 1914, inclusive, are on file in the Office of Farm Management.

There is good reason to think that the areas now occupied by the crowfoot-grama and needle-grass associations, at least in that part of the reserve where these associations meet, has about reached its normal productivity under complete protection. Some further replacement and substitution of species may take place, but no marked change in the total productivity is to be looked for. As nearly as the writer is able to judge, this condition has existed, on the area mentioned, for the past three or four years.

¹ Reported in detail in Bureau of Plant Industry Bulletin 67, p. 25 et seq.

Assuming these conclusions to be correct we find in our results from quadrat collections data of sufficient accuracy for making estimates of the normal productivity and, therefore, the normal carrying capacity of ranges of this character. With these as a basis, still further generalizations relative to other forage-plant associations are also possible, since they may be derived from the ratios of productivity of the different areas as shown by the collections.

TABLE II.—Average summer production of forage in certain parts of the Santa Rita Range Reserve, Ariz., as computed from the quadrat measurements made in 1912 to 1914, inclusive.

Name of plant association.	Number of collections used.	Total herbage.	All grasses.		Perennial grasses.		All perennial plants.	
		Weight per acre produced.	Weight per acre.	Part of total.	Weight per acre.	Part of total.	Weight per acre.	Part of total.
		<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Per cent.</i>
Needle grass.....	11	1,243	1,067	86	1,010	81	1,082	87
Crowfoot grama.....	23	1,045	972	93	864	83	932	89

Table II brings out an approximation to the relative productivity of the crowfoot-grama and needle-grass associations for three years, the former producing about 1,000 pounds of herbage per acre and the latter about 20 per cent more. This comparison may be a little unfair to the needle-grass association, since most of that area has been subjected to grazing, while the other has not. Another condition making against the accuracy of the comparison lies in the locations where collections were made. The 11 collections in the needle-grass association were mostly made near the lower edge of the area, where the effects due to the presence of stock are most noticeable. Of the 23 collections in the crowfoot-grama area, 18 are from the better parts of the area and only 3 are near its poorer boundaries. Thus the productivity of the needle-grass area as given is probably slightly below the average and that of the crowfoot grama is almost certainly a little above the average for its total area. They show nearly similar compositions, i. e., approximately 90 per cent of grasses, about 80 per cent of perennial grasses, and close to 90 per cent of perennials of all kinds.

Spring collections made in these areas have added very little to their total annual productions, though this would certainly be in favor of the needle-grass area, where no such collections have been made recently. Only seven spring collections have been made in the crowfoot-grama area, and they show a spring growth varying from 12 to 682 pounds per acre, the average of the seven being 178 pounds. Five of these collections, which were made after the summer growth began, show that the spring growth then constituted but a small part (from less than 5 per cent to about 33 per cent—77 per cent in

one collection) of the total vegetation on the area. In every case there was considerable perennial grass, never more than partly grown at the time of collection, thus increasing the apparent proportion of the spring growth. Estimates of the average productivity of the black-grama and six-weeks-grass areas, as made from the quadrat collections, would not be comparable with the results given in the table, mainly because neither of those areas has yet reached a state of normal productivity, and also because recent collections from these areas are not numerous enough to give fair averages. The only fall collection made recently in the black-grama area plainly gives too high a total production (1,210 pounds per acre) for an average annual productivity of that area. Another difficulty was encountered in making this collection, which applies to collections of wire grama also. These grasses do not die completely back to the ground in the winter; hence, it becomes very difficult to collect the growth of a single year, being absolutely sure that none of the growth of previous seasons has been included.

It will be very evident to the reader that the hay-cutting records are not directly comparable with the collections made on the quadrats. On the mowed areas the herbage obtained is only that part which can be cut by a mowing machine and picked up by a rake. On the quadrats every bit of vegetation above the surface of the ground was very carefully collected and weighed to an accuracy of 0.2 gram, a limit of accuracy which reduces to 1 pound of dried feed per acre. A number of collections were made on areas before they were mown and others on undisturbed areas besides the mown ones. While the number of these comparisons is not large enough to give a ratio which may be considered exact, the comparisons are at least quite suggestive. They are mostly easily seen in Table III.

TABLE III.—*Comparison of the total production of herbage per acre, as calculated from quadrat measurements, with the actual amounts of hay obtained from measured areas embracing or beside the quadrats, on the Santa Rita Range Reserve, Ariz.*

Location of cutting.	Data from quadrats.		Pounds of hay from 1 acre.	Percentage of total production obtained by hay-cutting operations.
	Quadrat No.	Total herbage in pounds per acre.		
Plat B, first cutting, near Proctor's camp (1.4 acres).....	26	1,372	1,037	74.8
Plat C, second cutting, near old haystack (1 acre).....	27	1,677	1,521	76.9
Ruelas in 1913.....	29	823	554	67.3
Felix in 1912.....	18	948	750	79.1
Felix in 1914.....	{ 48 49 }	876	794	90.6
Plowed acre near gate.....	16	1,609	750	40.6
Average.....		1,044	734	71.5

¹ The area was mowed the previous season, but no data were obtained. The collection represents the same growth as the hay cut, however, and they are therefore comparable.

Following is an attempt to estimate the total production on the fenced area. As computed from recent quadrat collections, the crowfoot-grama association produces about 1,045 pounds of summer forage and 178 pounds of spring forage per year, a total of 1,223 pounds per acre. The needle-grass association produces 1,243 pounds of summer growth and fully as much spring growth as the crowfoot-grama area, a total of 1,421 pounds at least. The productivity indicated by the single collection for the black-grama area, 1,217 pounds, is certainly more than an average, and the total annual production for the area is certainly not over 1,000 pounds per acre. The average production, as computed from the four spring and two summer collections from the six-weeks-grass area, is 871 pounds per acre. The remainder of the area does not produce over 400 pounds of forage per acre, if that much. A weighted average of the above figures, using round numbers, is as follows: Thirty-one sections of the first-named association at 1,200 pounds, 10 sections of the second at 1,400 pounds, 7 sections of the third at 1,000 pounds, 6 sections of the fourth at 800 pounds, and 4 sections of the last at 400 pounds. This accounts for the whole of the fenced area and gives an average production of 1,110 pounds of forage per acre.

An average of the total production of forage, as shown by the collections made in 1903,¹ 1904,¹ 1905,¹ 1907,¹ 1908,¹ 1912,² and 1914,² shows an average production of 1,160 pounds per acre. Thus two methods of computation reach practically the same result, which, in round numbers, may be taken at 1,100 pounds per acre as representing about normal productivity for this region.

If the figure representing average summer production on the crowfoot-grama area (1,045 pounds per acre), this being the area where all the hay cutting has been done, be compared with the average hay production (640 pounds per acre),³ it is seen that the haying methods get roughly 60 per cent of the annual growth. Stock will gather a crop more closely than the mower, but not so closely as the quadrat collections were made. They probably do get from 75 to 80 per cent of the crop produced each season on the open range, and this includes the spring as well as the summer growth wherever the range is stocked to the limit.

It is equally true that even as close collecting as the haying operations make, at a time no more unfavorable to the plants than when the hay is cut, ultimately results in a marked reduction of the total amount of feed produced. (See Table V for effect of repeated

¹ See Bureau of Plant Industry Bulletin 177, p. 19.

² Totals obtained from averages of all spring and summer collections during these years on file in the Office of Farm Management.

³ See Table IV, showing average weight of hay per acre. Table III gives actual comparisons on a few selected areas. The average result is probably too great.

cutting, p. 25.) Hence, in order to maintain productivity and prevent losses of stock in bad years, the range must be stocked at less than 60 per cent of its average productivity.

Assuming that a steer eats the equivalent of 30 pounds of dry forage per day, he will need about 11,000 pounds of forage in a year. If the average annual production of the grassed area is 1,100 pounds of dry forage per acre, then assuming that it is safe to put on enough stock to eat half of that amount annually, the average carrying capacity will be 20 acres per head per year if the range is to be maintained at its highest productivity.

THE MOST IMPORTANT FACTOR GOVERNING POSSIBLE IMPROVEMENT OF THE RANGE.

If it were possible to get a given area completely set in the best forage plants that would grow in the region, the productivity of the area would vary with the supply of water available to these plants during each growing season. All useless plants on such an area only waste the water which is so valuable for the production of feed. All run-off is complete loss of this precious moisture. It would seem to be desirable for a stockman to work toward the ideal condition as far as it is economically possible.

This is what the farmer in a humid region does, and he is able to modify and control the conditions on his farm only because the value of the product warrants the expense of its production. The stockman in the range country, whether his range be inclosed or open, is governed by the same principle, and on the open range he has the added uncertainty as to whether he himself will benefit by any labor he may expend in improving "his" range.

When it is remembered that much of the range land rents for 3 to 10 cents an acre per year without a fence, and that it requires from 15 to 50 acres to carry one cow through the year, one can appreciate how much may be expended economically upon the improvement of such land. It thus becomes apparent that the possibility of improvement rests entirely on a proper kind of management, and the possibility of the application of that management rests upon control. Yet there is a crop growing on this land and the cow has nothing to do but gather it. And if a man can get control of enough land, even of the poorest, and can get enough cows and other appurtenances of the business (Pl. VII, fig. 3), the output of meat animals, hides, wool, etc., will furnish him with a living. He may have to ride all over from 1 to 10 townships, but that is only an incident of the business.

HAY-CUTTING OPERATIONS.

STATEMENT OF CONDITIONS AND METHODS.

For the past five seasons—1910–1914, inclusive—hay cutting has been done in the protected area of the reserve and more or less complete records have been obtained. It must be kept in mind that hay cutting is possible over only a part of the protected area, and all of the hay cutting has been done upon selected areas where the conditions were the most favorable of any to be found in the field. Considered as a hay crop to be harvested, the forage produced on the reserve is at best so light as to raise some doubt as to the advisability of cutting it. And the conditions under which the work must be done are very unfavorable. Of the whole reserve, as indicated on the map, not over 20 sections of the ungrazed area receive enough summer rainfall to produce forage in sufficient quantity to be worth the cutting. And over much of this area the ground is too rocky or steep or broken or bushy to be mown. No water is available at any place inside the large field.

It follows that to do any hay cutting at all one must select an area of good grass land that is fairly level and free from rocks, bushes, and cacti. To this place must be brought the men, machinery, tools, wagons, etc., necessary for the work, and all the camp equipment and food necessary for the crew, both men and animals. Water for all camp purposes and all the animals, as well as grain feed, must be hauled to the camp, usually a distance of several miles. In nearly every case this outfit and crew have been brought from 15 to 20 miles, and most of the hay has been hauled the same distance (Pl. VII, figs. 1 and 2). And the roads of the region are nowhere very good for heavy hauling. It was impossible to bale the hay, on several occasions, because no baler was available. In a few cases the only available method of weighing the hay was by steelyards, and nearly all of the weighing was done, a bale at a time, on a small platform scale. In some of the larger cuttings the weight reported as the total is computed from the total number of bales and the average weight per bale of 15 to 25 bales actually weighed. The stacked hay was measured in all cases except two and the weight computed from the volume, which was obtained by the $F O W L^1$ rule and a weight factor to be explained later. The areas cut over were always quite irregular, but their acreage was obtained with a fair degree of accuracy in nearly every case. With these difficulties to be overcome, and the expenses entailed being limited by the economic possibilities of the situation alone, the records given in Table IV are submitted.

¹ See Bureau of Plant Industry Circular 131, entitled "Measuring Hay in Ricks or Stacks," p. 20.

TABLE IV.—*Record of all hay-cutting operations, Santa Rita Range Reserve, Ariz., 1910 to 1914, inclusive.*

Year and operator.	Total area.	Weight of hay.		Remarks.
		Total.	Per acre.	
1910. ¹	<i>Acres.</i>	<i>Pounds.</i>	<i>Pounds.</i>	
Felix.....	2.40	504	504	A single representative acre, measured; hay weighed.
Ruelas.....		595	595	Do.
Do.....		1,045	1,045	A single representative acre, measured; hay weighed; old grass.
Proctor.....		1,475	1,475	Do.
Do.....		572	572	A single representative acre, measured; hay weighed; burned over.
Do.....	1	1,036	1,036	Measured acre (plat A) near middle fence; hay weighed; first time cut.
Brown.....			640	A single selected acre, measured; hay weighed.
1911.				
Ruelas.....	31	11,480	371	Hay all baled and weighed
Do.....	5.3	3,360	634	Do.
Do.....	12	5,834	486	Hay stacked and measured; weight computed by <i>F O W L</i> rule. ³
Proctor.....	1	769	769	Measured acre (plat A) near middle fence; second time cut.
Do.....	1.4	1,482	1,037	Measured area (plat B) near Proctor's camp; weighed hay; first time cut.
Do.....	1	521	521	Measured area (plat C) near old haystack; weighed hay; cut over in previous year.
Do.....	29.9			Part of hay spoiled by continuous rain; total weight not obtained.
Nicholson	12	4 6,000	4 500	Hay stacked, not measured.
Brandt.....	33.5	17,240	514	Hay stacked and measured; weight computed by <i>F O W L</i> rule. ³
1912.				
Proctor.....	1	463	463	Measured acre (plat A) near middle fence; third time cut.
Do.....	1.4	969	692	Measured area (plat B) near Proctor's camp; second time cut.
Do.....	1	441	441	Measured area (plat C) near old haystack; third time cut.
Do.....	21.5	14,802	688	Hay stacked for six months.
Felix.....	1	750	750	Measured acre; hay weighed; first time cut.
Do.....	112	81,000	723	Hay baled, 1,800 bales; average weight of 25 bales=45 pounds; total weight computed.
Lauterbach.	5	4 3,000	4 600	Estimate based on weight of one load of loose hay.
1913.				
Ruelas.....	13.3	7,387	554	Measured area; hay baled and weighed.
Proctor.....	1.4	694	496	Measured area (plat B) near Proctor's camp; third time cut; hay baled and weighed.
Do.....	1	241	241	Measured acre (plat A) near middle fence; fourth time cut; hay baled and weighed.
Do.....	1	322	322	Measured area (plat C) near old haystack; fourth time cut; hay baled and weighed.
Do.....	9.8	6,556	669	Measured area; hay baled and weighed.
Do.....	21.9	15,596	712	Do.
Do.....	14.4	6,546	454	Do.
1914.				
Ruelas.....	28.6			Hay spoiled while waiting to be baled.
Do.....	6.9			Hay hauled in loose, not weighed.
Felix.....	114.2	90,717	794	Measured area; hay baled and bales counted; weight based on average of 65 bales weighed.
Proctor.....	1.4	526	376	Measured area (plat B) near Proctor's camp; hay baled and weighed.
Do.....	1	309	309	Measured area (plat C) near old haystack; hay baled and weighed.
Do.....	26.9	12,853	478	Measured area; hay baled and weighed.
Total Average.	552.8	290,894	650	

¹ Measurements for 1910 made by Mr. H. H. Jobson.² About.³ *F*=0.31, *O*=over, *W*=width, *L*=length of stack; 800 cubic feet of hay, stacked less than 30 days, =1 ton.⁴ Estimated.

Using all estimates as to weights and acreages, the average production per acre for five years has been 640 pounds of hay per acre.

Using the figures of only those instances in which the actual area is known and the total weight is also known gives an average of 558 pounds per acre. A comparison of these two figures would seem to indicate that probably some of the estimates were too high, thus increasing the average output of hay per acre for all cuttings. But a careful examination of the details of the records shows that it has so happened that all the records which show no element of estimate in them, except four, which are for small areas and therefore have little weight in the averages, are obtained from areas that have been mowed year after year for three to five years in succession, while many of the records which depend in any degree upon some one or more estimated factors are obtained from areas of medium to rather large size which were being cut for the first time. The hay from the latter kind of areas always contains a certain percentage of old grass which did not grow during the season that the hay was cut; hence, estimates of average production from such areas alone must be in excess of the average seasonal production. That estimates made from records of comparatively small areas which have been mown several years in succession must be somewhat under the average production will be seen by an examination of Table V, in which comparisons are given of the weight of hay cut from the same areas in successive years.

TABLE V.—*Comparison of the weights of hay cut on separate plats in successive years on the Santa Rita Range Reserve, Ariz.*

Number of cutting.	Plat A, near middle fence, 1 acre.			Plat B, near Proctor's hay camp, 1.4 acres.			Plat C, near old haystack, 1 acre.		
	Year.	Yield per acre.	Yearly decrease in production.	Year.	Yield per acre.	Yearly decrease in production.	Year.	Yield per acre.	Yearly decrease in production.
		Lbs.	Per ct.		Lbs.	Per ct.		Lbs.	Per ct.
First time.....	1910	1,036		1911	1,037		1910	(¹)	
Second time.....	1911	769	25.8	1912	692	33.3	1911	521	
Third time.....	1912	463	39.8	1913	496	28.3	1912	441	15.3
Fourth time.....	1913	241	47.7	1914	376	24.2	1913	322	26.9
Fifth time.....	1914						1914	309	4.0
Total decrease in productivity...	4 years.	795	76.7	4 years.	661	63.7	4 years.	212	40.6

¹ Plat C was cut in 1910 along with the rest of the area, but the weight of hay on this particular acre was not obtained separately.

From Table V it will be seen that continued cutting of the grass, year after year in succession, causes a gradual but marked decrease of the crop, ranging in quantity from 4 per cent to nearly 50 per cent of the previous year's growth, the average annual decrease being about 25 per cent. The average total decrease in production on the three plats for a period of four years is 64 per cent of the crop

of the first year. Since the first cutting always contains some old grass, the actual reduction of forage due to repeated cutting is less than the amount indicated, but is certainly quite large.

Evidence not quite so conclusive is shown by the cuttings made by Mr. Proctor on the larger areas, probably less conclusive because it has been his habit to cut over some ground each year that had not been mowed before. Records for 1911 on the 29.9 acres were not obtained, because considerable of the hay was spoiled by rain. The average production in 1912 of 21.5 acres (most of which had been mowed the two previous seasons) was 688 pounds per acre. In 1913, 9.8 acres of this same land gave 669 pounds per acre, while 21.9 acres, part of which had not been cut previously, gave 712 pounds per acre. Early in June, 1914, a fire burned all the old grass in the region Proctor usually cuts, so there was no old grass to be had that season. The average production on the 26.88 acres that he cut that year was 478 pounds per acre, which is about 100 pounds per acre lower than the general average. Doubtless this was the result of the fire, which was more than normally effective because growth of the grass had already begun when it occurred. The records for the three years show a decline in productivity, which is doubtless attributable to continued cutting.

The only other factor which might influence these results would be the seasonal rainfall. From what has already been said about the "spotted" character of the rainfall, it follows that our records taken only a few miles away do not tell the actual facts with regard to the amount of water that fell upon these areas during the different growing seasons. But since the total seasonal rainfall on each plat was probably closely parallel to the records obtained at MacBeath's and at McCleary's, it is well to compare these figures for the different years under consideration. Since it is the seasonal rainfall only that affects the amount of forage here considered, it will be important to note the records of precipitation for June, July, August, and September, in the years 1910-1914, inclusive, as shown in Table VI.

TABLE VI.—*Comparison of summer rainfall records at two points on the Santa Rita Range Reserve, Ariz., 1910 to 1914, inclusive.*

Month.	McCleary's house.					MacBeath's house.				
	1910	1911	1912	1913	1914	1910	1911	1912	1913	1914
June.....	0.69	1.51	0.56	1.46	1.55	0.57	2.04	0.27	0.42	3.44
July.....	5.10	8.40	8.62	3.58	4.99	4.64	5.05	5.89	5.15	4.09
August.....	4.41	1.17	3.49	3.51	3.79	3.94	2.96	3.69	4.59	6.48
September.....	.51	1.56	0	.67	1.21	1.02	3.79	.70	1.94	4.08
Total.....	10.71	12.64	12.67	9.22	11.54	10.17	13.84	10.55	12.10	18.09

It is thus shown that while the growing season began a little earlier in 1911 and in 1914, there was sufficient rainfall each summer to produce the normal crop. But there is no continuous diminution of the precipitation from the first of the period to the last of it. In fact, 1914 was the rainiest year of the five, though all the plats show the least production during that year.

THE WEIGHT OF ARIZONA RANGE-GRASS HAY IN THE STACK.

The method used for the measurement of hay in stacks is to compute the volume of the stack and divide this result by the volume which weighs a ton of the given kind of hay. In computing the weight of Arizona range-grass in the stack, no data for obtaining this volume were available. In 1912, however, an opportunity for a single record was offered. That fall the press of other work made it necessary for Proctor to stack his hay and bale it later. The hay from 22½ acres was stacked and measured. In March, 1913, the stack was measured again and the hay was baled and weighed. Using the *F O W L* rule for computing the two volumes of the stack and dividing each by the total weight of the hay, it was found that of the newly stacked hay 861 cubic feet weighed 1 ton, while only 657 cubic feet of the old hay weighed as much. Since the first measurement was made when the hay was first stacked, it was assumed that 800 cubic feet of hay in the stack standing less than 30 days would weigh approximately 1 ton, and this factor was used in our computations. So far as the writer has been able to learn, this is the first record of definite measurements for the actual weight of Arizona range-grass hay in the stack.

THE COST OF MAKING RANGE HAY ON THE SANTA RITA RESERVE.

Only one set of records as to the cost of making range hay on this reserve has been obtained. In 1914 an area of 114.2 acres was mown which yielded 45.36 tons of hay. The crew required for the work was 8 men, a cook, and 6 horses. The machinery equipment consisted of 2 mowing machines, one 1-horse rake, one 2-horse buck rake, a baler, and 2 wagons, with the necessary harness, water barrels, and hand tools. The wages paid the men ranged from 75 cents to \$1.25 per day and board, each man furnishing his own bedding. Allowing 25 cents a day per man for food, the total cost for food was \$35. The grain and provisions came from the farm of the operator. The horse work done was as follows: 24 horse-days mowing, 12 horse-days raking, 20 horse-days bringing the hay to the baler, 20 horse-days baling, and 6 horse-days coming to the reserve, besides the necessary trips for water (3 miles and return for a load). The work required 12 man-days for the mowing, 12 man-

days raking, 10 man-days with the buck rake, and $95\frac{1}{2}$ man-days for the baling. The total expense for man labor was \$122.35. Allowing 50 cents per day for a horse's work and his feed (which is about fair for the character of the teams and the amount of grain fed in this work), the horse work cost \$41. Besides the regular provisions, a young beef worth probably \$25 was killed and the meat used. The total cost of putting up 45 tons of hay was approximately \$225, or \$5 per ton. Two men, 8 horses, and 2 wagons were kept busy for 16 days hauling 40 tons of this hay to the home of the operator about 18 miles away, thus adding \$2.40 more per ton to the cost of the hay. This allows nothing for depreciation on machinery, which should be quite heavy considering the character of the work. Some of this hay was sold at the baler before weighing, at the rate of \$5 for 30 bales. The hay sold gave the operator about 50 cents per ton as net gain besides paying him \$1.25 per day as wages and \$1 a day per team for his animals, both of which prices are to be considered as good pay in the region for the character of the work performed.

GRAZING EXPERIMENTS.

The most instructive data so far obtained upon this reserve are those which have resulted from the actual carrying of stock on measured areas. Records have been kept as to the movement of stock on the pastures of four individuals for several years. From these records it is possible to compile: (1) The actual number of days' feed for one mature animal that each pasture has furnished each month, (2) the average number of animals carried by each pasture for each month and each year, and (3) the apparent carrying capacity of the areas for each year. These data have been summarized in Table VII and are visualized in figure 5.

The pastures have been handled independently by the users and according to the judgment of each man as to his own best method. The custom of the region (which had been followed by some of these men before, and continued by three of them since the area was placed under control) is to stock as heavily as the range will carry all the time.

TABLE VII.—*Stock grazed on individual pastures on the Santa Rita Range Reserve, Ariz., 1908 to 1914, inclusive.*

FELIZ RUELAS, OPERATOR.

Month.	Year.													
	1908		1909		1910		1911		1912		1913		1914	
	Total animal - days' feed.	Average number of animals.	Total animal - days' feed.	Average number of animals.	Total animal - days' feed.	Average number of animals.	Total animal - days' feed.	Average number of animals.	Total animal - days' feed.	Average number of animals.	Total animal - days' feed.	Average number of animals.	Total animal - days' feed.	Average number of animals.
January.....	.....	.....	2,709	87	2,044	66	2,697	87	2,170	70	2,904	94	1,860	60
February.....	.....	.....	2,652	94	2,352	84	2,436	87	1,960	70	2,688	96	1,464	52
March.....	.....	.....	3,397	110	2,604	84	3,172	102	2,170	70	3,548	114	1,333	43
April.....	.....	.....	4,660	155	2,052	68	3,360	112	2,100	70	4,554	147	1,290	43
May.....	.....	.....	5,937	191	2,833	91	3,274	106	1,855	60	4,290	138	990	32
June.....	.....	.....	5,250	178	2,002	67	2,820	91	1,050	35	1,080	36	1,140	38
July.....	.....	.....	3,875	125	1,085	35	899	29	899	29	1,116	36	1,178	38
August.....	.....	.....	1,685	54	4,495	145	1,155	37	1,371	44	1,116	36	1,298	42
September.....	.....	.....	3,150	105	2,250	75	1,350	45	1,710	57	1,506	50	1,740	58
October.....	.....	.....	3,400	110	2,629	85	1,775	57	1,763	57	1,581	51	2,533	81
November.....	4,500	150	2,100	70	2,730	91	1,350	45	2,214	74	2,135	71	3,615	101
December.....	2,743	89	1,876	61	2,821	91	1,845	59	2,604	84	1,860	60	3,348	108
Total....	7,243	119	40,791	112	29,897	82	26,133	71	21,866	60	28,378	78	21,189	58
Acres per head ¹	6.3		8.6		13.0		14.8		17.8		13.7		18.3	

CHARLES A. PROCTOR, OPERATOR.

January.....	.....	.....	.....	.....	3,122	101	2,077	67	1,856	60	3,510	114	3,680	119
February.....	.....	.....	.....	.....	2,700	97	1,769	63	1,792	64	3,306	114	3,479	125
March.....	.....	.....	.....	.....	3,641	117	1,874	60	2,719	90	3,794	122	4,279	138
April.....	.....	.....	.....	.....	2,473	82	2,200	73	4,179	139	4,171	139	5,328	177
May.....	.....	.....	.....	.....	2,695	87	3,689	102	3,999	129	5,131	166	6,102	212
June.....	.....	.....	3,750	125	3,971	132	4,756	158	4,650	155	6,641	221	4,770	159
July.....	.....	.....	1,085	35	5,328	172	4,263	138	5,239	169	7,168	231	4,944	160
August.....	.....	.....	1,798	58	2,110	68	1,457	43	4,261	136	2,852	92	3,004	97
September.....	.....	.....	1,230	41	2,055	68	1,410	47	4,197	140	2,588	86	2,926	97
October.....	.....	.....	3,401	110	2,165	70	1,495	48	3,653	118	2,663	86	3,863	125
November.....	.....	.....	2,430	81	2,494	83	1,920	64	3,210	90	2,754	92	4,110	137
December.....	.....	.....	3,108	100	2,255	73	1,984	64	2,845	94	2,708	87	4,490	145
Total.....	.....	.....	16,802	78	35,009	96	28,894	77	42,600	110	47,286	129	50,975	141
Acres ¹ per head	.....		21.5		17.3		21.9		14.5		13.0		12.1	

W. B. MacBEATH, OPERATOR

January.....	2,083	67	3,874	154	3,729	120	5,278	170	2,045	66	2,150	69	7,292	235 ²
February.....	2,320	80	3,747	134	3,316	107	4,872	174	2,576	89	2,397	86	6,182	221
March.....	3,050	98	4,686	151	3,736	121	5,747	186	3,714	120	3,249	105	7,693	248
April.....	3,409	113	4,905	158	4,840	161	6,921	231	3,510	117	5,613	187	8,396	279
May.....	3,660	118	5,192	167	5,628	181	7,216	233	4,253	137	4,429	143	9,020	291
June.....	4,290	143	4,990	166	6,417	214	7,033	234	4,890	163	6,626	221	8,785	293
July.....	4,153	134	5,040	163	6,325	204	6,449	208	5,526	178	8,494	274	8,029	259
August.....	3,948	127	4,470	138	5,786	187	4,375	141	2,865	92	5,167	167	3,221	104
September.....	3,240	108	4,247	137	4,565	157	3,300	110	2,454	82	3,494	116	9,150	65
October.....	3,418	110	4,340	140	4,557	147	2,656	86	1,608	52	3,031	98	1,565	50
November.....	3,247	108	3,630	121	4,485	149	1,946	65	1,654	55	3,365	179	1,200	40
December.....	3,205	103	3,705	120	4,828	156	2,139	69	1,674	54	7,302	236	2,128	69
Total.....	40,023	109	52,826	146	58,212	159	57,932	159	36,769	100	57,317	157	72,661	179
Acres per head	15.3		11.6		10.5		10.2		18.8		12.0		9.5	

¹ The figures in the line "Acres per head" show the average number of acres of land necessary to carry one mature animal one year. This result is found by dividing the total acreage by the average number of animals pastured.

TABLE VII.—*Stock grazed on individual pastures on the Santa Rita Range Reserve, Ariz., 1908 to 1914, inclusive—Continued.*

W. B. McCLEARY, OPERATOR.

Month.	Year.									
	1908		1909		1910		1911		1912	
	Total animal-days' feed.	Average number of animals.	Total animal-days' feed.	Average number of animals.	Total animal-days' feed.	Average number of animals.	Total animal-days' feed.	Average number of animals.	Total animal-days' feed.	Average number of animals.
January.....	230	7	290	9	168	6	465	15	434	14
February.....	210	7	246	8	234	8	364	13	394	14
March.....	238	8	250	8	356	11	430	14	403	13
April.....	210	7	270	9	352	12	496	17	420	14
May.....	209	7	240	8	405	13	527	17	429	14
June.....	216	7	248	8	438	15	510	17	470	20
July.....	225	7	302	10	442	14	527	17	510	16
August.....	240	8	278	9	445	14	434	14	583	19
September.....	237	8	600	20	450	15	492	16	570	19
October.....	271	9	233	8	368	12	527	17	589	19
November.....	260	9	289	10	380	13	480	16	510	17
December.....	271	9	367	12	399	13	470	15	432	14
Total.....	2,817	7	3,613	10	4,437	12	5,722	15	5,744	16
Acres per head	103.1		80.2		65.6		50.9		50.5	
									53.2	
										63.5

Since the fenced area available to each man is relatively small, and since each of them has just as much right to the use of the open range outside his fence as anyone, it has been their custom to watch the condition of the feed outside their pastures and the condition of their stock at all times and to carry their stock on the outside feed just as much of the time as possible. This policy causes them to turn out stock as soon as the feed outside warrants it, a procedure that results beneficially for the fenced pastures, because it allows the plants inside the fence to grow to the best advantage during the growing season. The control given by the fence makes it possible to save this feed until the outside feed is mostly eaten, when the stock can be brought inside on good grass. This method of treatment throws the greater part of the burden upon the outside range and tends to build up the carrying capacity of the inclosed area.

Under such a method, if the fenced area is stocked to its full capacity, but not overstocked, the carrying capacity derived from the numbers actually carried is probably a little in excess of what might be expected from the same land if stocked to its legitimate limit all the time. For this reason the carrying capacity indicated in Table VII and the diagram (fig. 5) may be a little too large. But this conclusion is not true if for any reason the pastures have not been stocked to their limit, or if they have been overstocked, either of which conditions may have arisen.

To understand these possibilities it is only necessary to call attention to two or three factors which would affect the result. If for any reason a pasture were understocked there would be excess feed on it, but the figures for average monthly and yearly numbers carried, as well as the average carrying capacity, would be lowered. Such a condition might arise if the stock-water supply should diminish or fail, a condition that did obtain for some time on the Ruelas place during 1913 and part of 1914.

If, because of exceptionally high prices, a man should sell a large part of his stock and not restock at once, or if, for any reason, he should be forced to sell or was unable to buy whenever his pasture warranted it, the number of animals on the pasture would be less

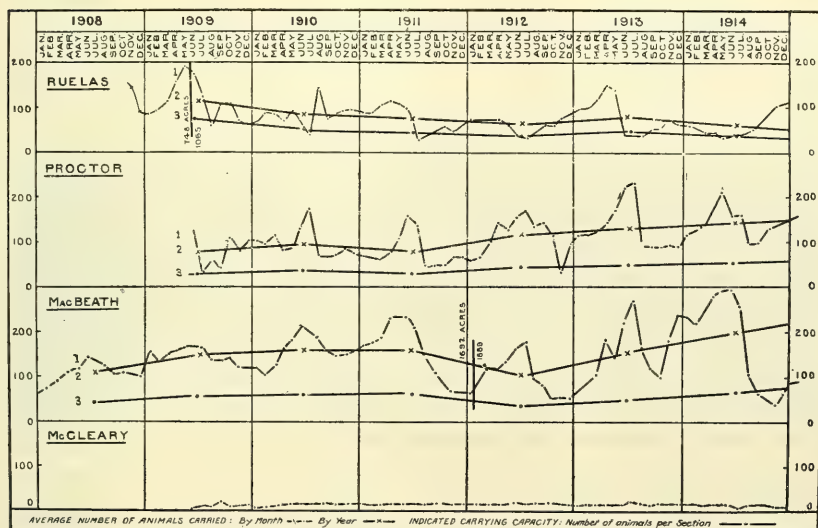


FIG. 5.—Curves showing variations in the rate of stocking on those parts of the reserve that have carried stock for the past six years. The curves numbered 1 show the average number of mature animals (cattle, horses, or burros) carried on each pasture, by months, for the full period. Curves numbered 2 show the same data by years. Curves numbered 3 show the average carrying capacity in acres per head per year for each pasture during the period of observation. Curves numbered 3 rest upon the assumption that the pastures have been stocked to their legitimate limit each year.

than it could carry, and all the figures relating to numbers carried and carrying capacity would again be below what the feed in the pasture might warrant.

Again, if the user should overestimate the capacity of his range and put on more stock than it could properly carry, the result would be an increase in all the figures, at least for a time, and a noticeable drop at a later period. Seasonal climatic variations of marked degree also would tend to decrease all values if unfavorable and to increase them if favorable to the growth of forage, though such variations would tend to counteract each other during a series of years.

There can be no question that the productivity of the areas which have been pastured is normally greater than the average for the whole inclosed area, because these pastures lie in that part of the grassed land which gets the most water. (See p. 8.)

The forage-distribution map (fig. 3) shows a small patch of six-weeks grass in each of the pastures, a condition which would seem to indicate that these pastures may be somewhat overstocked. The general opinion of the various men is that their pastures have improved under protection, and these poorly grassed areas may be the remnants of larger areas that are being gradually replaced, though more slowly than on the completely protected area.

In the opinion of the writer, the pastured areas have not deteriorated noticeably since July, 1911, nor have they materially improved. He believes that during that time they have been kept at about uniform productivity, but slightly below their maxima. The result of this is to make the carrying capacity appear a very little larger in figure 5 and in Table VII than it actually is.

The above remarks apply with most force to the MacBeath pasture, less so to the Proctor pasture, and hardly at all to the Ruelas pasture. It should be understood that McCleary has not been running cattle upon his pasture. He has had it lightly and about uniformly stocked with horses and burros. These animals have been on the land continuously with little or no shifting, and the range which was unable to carry stock at the rate of 29 acres per head in the earlier days of the experiments¹ is now not noticeably different from the completely protected area lying immediately north of it. It is hardly possible to tell by the condition of the grass that there is any stock on this area. From such data it is perfectly certain that 50 acres per head per year is considerably under the carrying capacity of such range pasture.²

It is almost certain that stocking heavier than 53 animals per section (12 acres per head per year) on the MacBeath place and between 45 and 50 animals per section (13 or 14 acres per head per year) on the Proctor place is not warranted by the present condition of these pastures, under their present form of management. It is more difficult to get an estimate for the Ruelas place, because other important but as yet unmeasured factors enter the problem. From the standpoint of feed alone, the Ruelas pasture will doubtless carry as much per section as the MacBeath place, but for some time past the supply of stock water has been insufficient for all the stock which the pasture would carry.

¹ See Bureau of Plant Industry Bulletin 177, p. 21.

² The horses on this area have very light work and little of it. They are always fed a small amount of grain whenever they are worked; at other times all their feed is the native grass grown on the area.

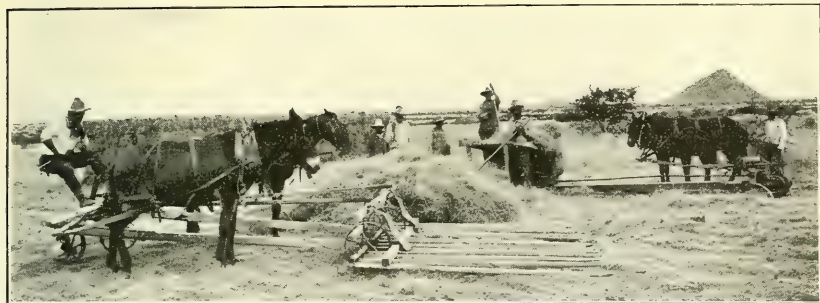


FIG. 1.—BALING HAY ON THE SANTA RITA RANGE RESERVE IN SEPTEMBER, 1914.



FIG. 2.—BALED HAY ON THE RESERVE READY TO BE HAULED TO A FARM IN THE VALLEY, 25 MILES AWAY.

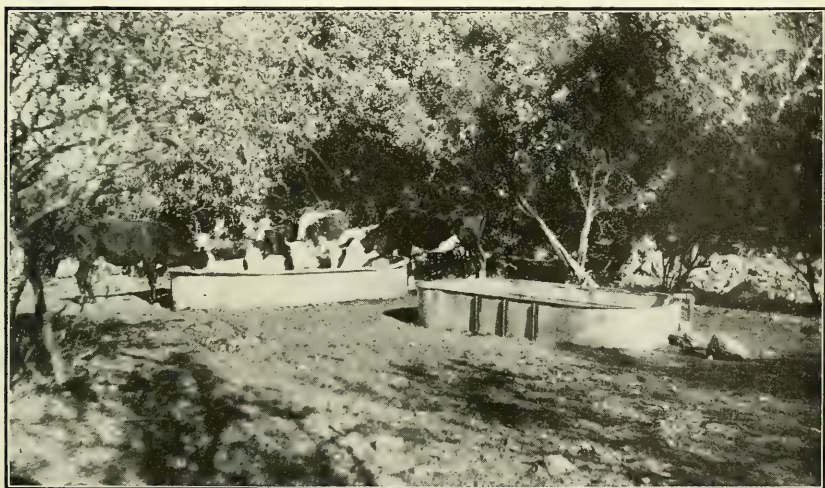


FIG. 3.—ONE OF THE WATERING PLACES IN MACBEATH'S PASTURE, ON THE RESERVE.

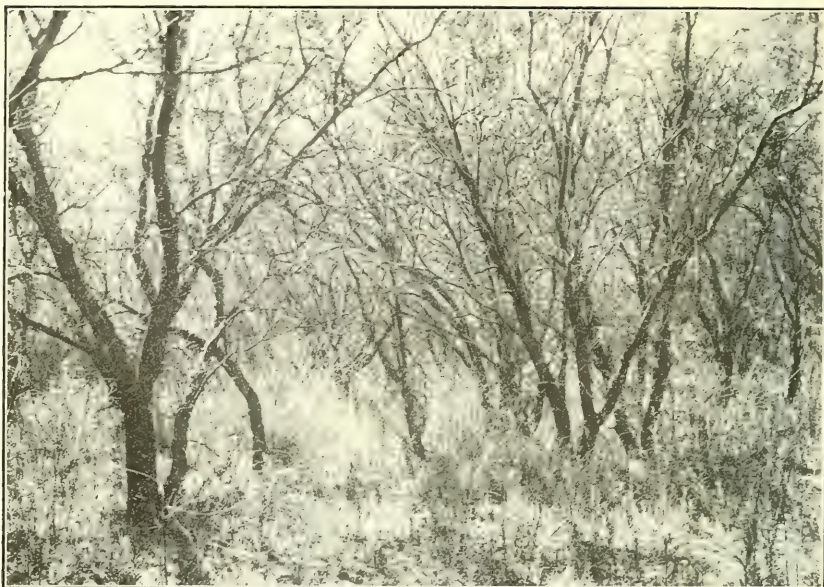


FIG. 1.—A DENSE GROWTH OF MESQUITE BUSHES IN STONE CABIN CANYON, ON THE SANTA RITA RANGE RESERVE.

Some stools of saccaton (*Sporobolus wrightii*) are shown near the center of the picture. This grass thrives where other grasses are killed by the shade.



FIG. 2.—A SINGLE MEDIUM-SIZED MESQUITE BUSH ON THE RESERVE, SHOWING ITS CROP OF BEANS ON THE GROUND.

The dried beans from this bush weighed 10¼ pounds. These beans are very nutritious and are eaten freely by all kinds of stock.



FIG. 1.—CONDITIONS IN AN ARROYO, SHOWING HOW THE GRASS RETARDS EROSION AND HELPS TO FILL IN WASHED PLACES ON THE SANTA RITA RANGE RESERVE.

Hundreds of places may be found on the reserve where different stages of this process of leveling up are in progress.



FIG. 2.—THE BOUNDARY FENCE BETWEEN THE MCCLEARY (LEFT) AND MACBEATH (RIGHT) PASTURES IN MAY, 1914, SHOWING THE EXTENT TO WHICH THE FORAGE ON THESE PASTURES IS FED OFF EACH SEASON.

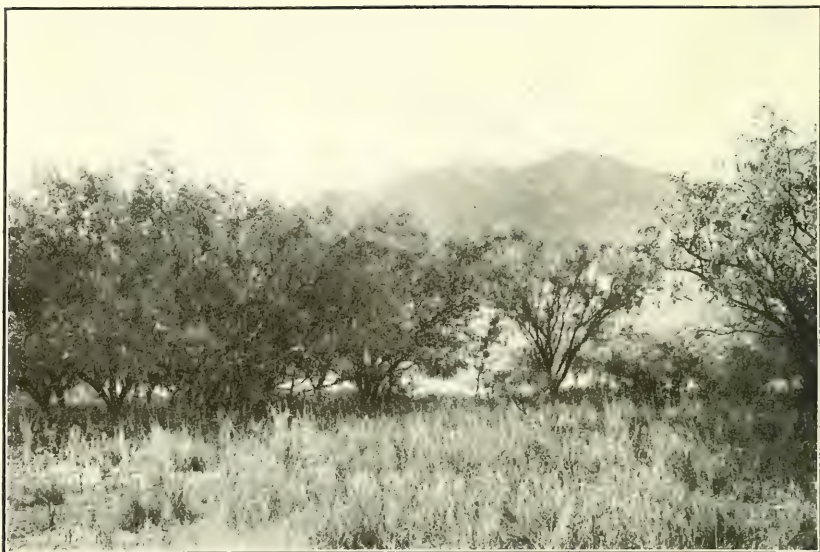


FIG. 1.—AN OPEN SPOT AMONG THE MESQUITE BUSHES ON THE SANTA RITA RANGE RESERVE.

A good stand of grass has been obtained by persistent sowing. (Compare with fig. 2.)

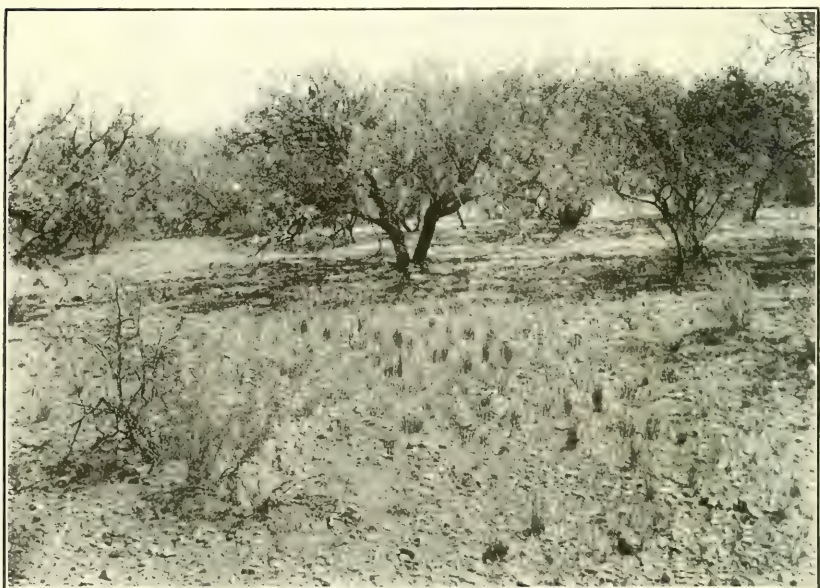


FIG. 2.—A SIMILAR OPEN SPOT, SHOWING THE BEGINNING OF THE GROWTH OF GRASS.

No results were obtained on this spot (which is less than 100 yards from the other) for several seasons, though seeds were scattered each year. (Compare with fig. 1.)

If allowance is made for the facts (1) that these pastured areas produce more feed than other parts of the area under observation, (2) that they are carrying more under the present form of management than they would if an average number of animals were kept on them continuously, and (3) that there is some indication that they are slightly overstocked, it is seen that the results obtained from the pasturing experiments are in reasonably close agreement with the average for the whole reserve derived by other means and presented elsewhere in this bulletin. (See p. 21 et seq.)

MISCELLANEOUS NOTES.

The effects of fire.—The complete protection of the reserve for a number of years has resulted in a rather heavy crop of dry grass, which burns readily, especially in the dry, hot weather of May or June, just before the summer rains begin. Several such fires have occurred, due to lightning, carelessness of passers, or incendiarism. The only serious damage they do is to burn off the fence posts and let the fences fall. These fires are always extinguished as quickly as possible after they start, but sometimes considerable areas have been burned over. Attention has been called to the effect on the mesquite bushes. The spines of the cacti are usually singed off, and some of the stems blistered, and a few are killed. *Opuntia spinosior* seems to suffer more seriously than any of the other species. In June, 1914, occurred one of the largest and hottest fires, which burned over about four sections of the heaviest grass. Along the arroyos where the grass was highest and thickest the mesquite bushes were killed completely in several places, and many were killed back to stumps. The following growing season on the burned area there was a much larger proportion of annuals in the summer collections and a particularly noticeable abundance of one grass, *Bouteloua parryi*, which has not been observed in any abundance recently. It was common in many parts of the reserve in the earlier years of the experiment. Whether or not the burn was responsible for these occurrences the writer is unable to say. The fire was doubtless responsible for a noticeable decrease in the hay crop obtained on part of the burned area this season.¹ Of the grasses, *Bouteloua eriopoda* and *Heteropogon contortus* suffered most, though old stools of *Aristida divaricata* also showed retardation and some killing.

The mesquite bean crop.—An important part of the forage of this region is furnished by the herbage and flowers of the cat's-claw (*Acacia greggii*) and the mesquite (*Prosopis velutina*), as well as by beans of the latter. Two measurements were made of the crop of mesquite beans from medium-sized trees in 1914. The blossoming

¹ See Table IV, p. 24: Proctor's records for 1914.

season of 1914 seemed to be very favorable, but very few trees set fruit. The data as to measurements are as follows:

One tree about 1 mile nearly east of the location marked I on the map (fig. 2), 9 feet high, with a spread of 10 feet, produced as second crop 10 $\frac{3}{4}$ pounds of dried beans (Pl. VIII, fig. 2). Another tree near McCleary's house, 9 feet high and with a spread of about 14 feet, produced 10 pounds of dry beans as a first crop. Probably 60 per cent of the trees on the reserve are as large or larger than the two measured.

Erosion retarded.—The process of leveling the land by the action of water, assisted by the growth of vegetation, has been going on ever since the stock were put out of the reserve and the plants commenced to reestablish themselves. It has been carried to completion in some of the shallower arroyos, and the bottoms of the watercourses are entirely covered with plants. The larger arroyos still have well-marked sandy channels where nothing but coarse annual weeds grow, but the grasses are rounding off the banks of such channels and gradually diminishing their width, while in many places they prevent further erosion by growing directly in the narrow cut and helping to hold whatever earth may be washed in by the run-off (Pl. IX, fig. 1).

Seed sowing.—Numerous attempts at reseeding have been made on this range reserve and elsewhere, the results of which have been reported in previous bulletins.¹ Most of the attempts have resulted negatively. Particularly is this true with reference to introduced species, although these have been selected with the best judgment obtainable as to the requirements of the region and the possible adaptiveness of the species tried. It by no means follows that nothing will ever be found that will suit the conditions, and there is believed to be good reason for expecting that some valuable finds of this kind will be made in regions not yet carefully explored with these desires in mind.

The alfalaria, previously reported as seeming to take hold, has since been entirely crowded out by the native perennial grasses. Several annuals that gave some promise have also given way to the native perennials.

Trials of Sudan grass were made at three different places on the reservation in 1914—near MacBeath's house, near McCleary's, and in the large field on the plowed ground (near H, fig. 2). The seeds germinated well at each place, but the young seedlings were not able to bear the dry weather that occurred after the first rains. Plants at MacBeath's which were watered during the first dry spell made a good growth (about 3 feet) and produced some seed. Plants

¹ See Bureau of Plant Industry bulletins as follows: No. 4, reporting results on a small range near Tucson; No. 67, giving later results on the same area; No. 117, treating of methods and results of reseeding in general; No. 177, treating of results on this range.

that were not watered grew about 3 inches high or less. It is very doubtful if a crop of this grass can be grown without irrigation, even on that part of the reserve that receives most water.

Not so unsatisfactory, however, are the results obtained by scattering seeds of the native grasses upon the bare spots, even where the soil conditions are not good. For a number of years it has been the habit of Mr. McCleary to scatter seeds of the local native grasses upon bare spots in his pastures. Since hay cutting has been going on, it has been possible to get seeds in some quantity at the hay baler, and he has taken advantage of this means and has each year scattered seeds in considerable quantity. Many gravelly slopes that would otherwise have remained bare are now grassed as the result of this treatment. (Pl. X, fig. 1.) Other things being equal, this method will get results in the course of two or three years that would occur much more slowly without scattering the seeds over the ground, though difficulty in getting germination sometimes occurs. (Pl. X, fig. 2.) This method of reestablishing the native species is very inexpensive and seemingly warrants the time and effort.

Experiments with sheep.—After the large field had been under fence for a number of years and the crowfoot-grama area had shown considerable improvement, an arrangement was made to try feeding off with sheep that part of it lying north of Box Canyon. A supply of water was developed in the canyon and a small band of sheep (about 1,200 head) was put on the area in the early spring. They stayed on the reserve about 60 days and were under the care of a Mexican herder, just as sheep are handled on the open range. While there was apparently an abundance of feed for such a band, the animals did not improve. As the dry spring and early summer weather began the water supply gave out and it was necessary to move the sheep. The next spring another trial was made in the same way. A small band was put on the reserve. These sheep were in very much weakened condition when they went on the reserve, but they did not recover as it was hoped they would on the abundant dry feed to which they were taken. They were on the reserve from February 22 to May 16, and lambled during the 30 days beginning March 18. In May, as they were leaving the reserve because of failure of the water supply, there were 440 ewes and 260 lambs in the band, and they were all in very poor condition.

The results of these experiments indicate that the grass of this region is not good feed for sheep, because it is too dry at the time of year when sheep need succulent feed to produce milk for the lambs. Dry feed at lambing time and while the lambs are young is unfavorable to the business in several ways, even though there is an abundance of the feed. Since the perennial grasses have dominated most of the better part of the reserve, the production of spring annuals has decreased quite markedly, and the spring feed for sheep is not as

good as formerly. The quantity of feed produced, however, has increased very much, and the change in kind has shown quite conclusively what every stockman already knew, i. e., that the region is better adapted to cattle and horses than it is to sheep. The grazing of these small bands of sheep on the range reserve did not affect the range in any way detrimentally in the short time they were there. It was hardly possible to see where they had been running except about the bed grounds, though the herder's camp was not moved while he was on the reserve.

FUTURE INVESTIGATIONS.

Summarizing the data so far collected on the Santa Rita Range Reserve has not only shown the results obtained, but has pointed out several lines along which further data should be collected by continuing work in progress, and it has also suggested some new lines of investigation.

Besides keeping watch on the rate of spread of the various grass associations mentioned in this bulletin, it is very desirable to devise some way of measuring the productivity of the black-grama association more accurately than has heretofore been possible. Special attention should be paid to its rate of spread in the northwest corner of the reserve. The question of whether it will supplant the crowfoot-grama association at the lower levels is one of great importance, as is the time it will take for the black-grama association to cover any given area.

Some accurate measurements as to the rate of spread of the long-lived perennial grasses like *Heteropogon contortus* and *Bouteloua eripoda* are desirable, as are more data on the productivity of the six-weeks-grass areas. The rate of recovery and factors affecting it on the plowed areas should be studied carefully. Some seeding experiments with the local species should be tried in the extreme northeastern corner where these grasses have been very largely killed out.

Assuming that that part of the recovery pasture lying east of the Helvetia road has about reached its normal productivity, it would seem to be wise to establish an experiment to determine just what the carrying capacity of this area is, by grazing off the forage crop with a definite number of animals that are kept on it all the time, this number to be based upon estimates already obtained from quadrat measurements and hay-cutting records.

SUMMARY AND CONCLUSIONS.

The conditions under which the series of experiments of which this bulletin is a report of progress were carried on are set forth in the introduction. An attempt is here made to summarize the results so far obtained, those reported in previous bulletins being included for the sake of completeness.

Recovery.—It is the unanimous opinion of all who know the region that the carrying capacity of the completely protected area has improved very much over its condition at the beginning of the experiments. There is likewise no doubt that the carrying capacity of the inclosed areas under stock is now greater than that of the adjacent unfenced land of similar character.

Rate of recovery.—Previous publications relative to this project have stated that recovery of that part of the reserve inside the large field and lying above the 3,500-foot contour occurred in marked degree in about three years after inclosure. The improvement in that area since that time has continued, but the increase in productivity has been growing less and less each year, indicating that that part of the reserve has now about completely recovered. The area of increased productivity has been gradually spreading until all parts of the inclosure are now more or less improved. In the opinion of the present writer, that part of the reserve below the 3,200-foot contour may be expected to continue to improve for a number of years more, under protection, and the recovery experiment should be continued at least until such time as complete recovery of this area is obtained.

Some definite answers are now available as to the time necessary for recovery under different conditions. Three years of complete protection gave about three-fourths of complete recovery for the area where crowfoot grama is the dominant grass, at levels of about 3,500 to 4,000 feet, where an annual rainfall of 15 to 18 inches occurs. One inclosed pasture of this type having an area of 794 acres, which has been stocked with horses and burros at the average rate of about 11 head per section, recovered somewhat more slowly than the completely protected area beside it and at the same level, but after 11 years protection is now not appreciably different in carrying capacity from the completely protected area, a condition which has obtained on this pasture for the last two or three years. This would indicate that this pasture recovered under light stocking in about double the time required for the completely protected area. Areas at higher levels might be expected to do at least as well if not better under similar treatment.

Three other areas, 1,065, 1,695, and 1,889 acres in extent, respectively, which have been judiciously pastured with approximately all the cattle they could carry, are known to show better productivity than adjacent unprotected grazing land of the same character; and by their users these areas are believed to have materially increased in carrying capacity under this kind of treatment within a period of 11 years. Table VII and the curves in figure 5 show a gradual increase in numbers carried on the two larger areas. Hence, if these pastures have been stocked to their proper limit all the time and the condition of the pastures has not declined, the curves indi-

cate approximately the increase in carrying capacity under the treatment imposed. The factor of occasional insufficiency of stock water has interfered with the stocking of the other pasture and modified the results. In general, therefore, it may be said that, other things being equal, the rate of recovery in this region varies with the available moisture. With complete protection the better part of this range recovered rapidly at first, large gains being made in the first two or three years, and approached complete recovery in 10 or 12 years. The poorer parts of the range are much improved after 11 years' protection, but are probably not yet completely recovered. Light stocking of the better part of the range with horses (approximately one-third of the stock it could carry) doubtless retarded the rate of recovery, but after eight or nine years this animal factor was negligible. Heavy stocking with cattle has not prevented but has retarded recovery, so that after 11 years the grazed areas are but partially recovered, though their carrying capacity has increased not less than 30 per cent and possibly more in that time.

Reseeding operations.—Practically all attempts to introduce new species of forage plants or to increase the relative abundance of particular endemic species beyond their natural importance in the plant associations of the region have resulted negatively. In a few cases introduced plants like alfalaria or some aggressive annuals have seemed to promise some returns, but in the course of a few years the native perennials have crowded them out. By far the greater number of the species tried have given nothing but negative results from the first.¹ The scattering of seeds of the local native species upon bare ground has proved to be well worth the trouble, since the practice has resulted in the more rapid recovery of such areas. This procedure has also put a crop of grass upon some soils where it was predicted that nothing would grow. The policy of scattering the seeds of the best grasses of a region on the denuded areas is to be recommended to stockmen generally wherever the seeds can be had in any quantity at relatively small expense, as is always the case where range hay is baled. On areas of large size which have been denuded of their best native grasses a seemingly large expense is warranted in order to get seeding plants of such grasses established on the area. Generally speaking, the seeds of native species of this region do not need to be covered, since they are mostly able to bury themselves deep enough to cause germination, at least under favorable climatic conditions.

Carrying capacity.—An attempt is here made to work out an expression representing the average carrying capacity of the whole range reserve, in the belief that this result will apply to a large part

¹ See Bureau of Plant Industry Bulletins 117, p. 22; 177, p. 12.

of southern Arizona and possibly to an even larger area. Records of four kinds have been obtained.

(1) Collections of everything growing upon small measured areas (quadrats) have been made for a number of years in representative parts of the range reserve, and from the weights of the dry material collected the total productivity in terms of pounds of forage per acre has been calculated. These records extend over a period of nine years. From each year's collections an average for the year has been obtained. From these yearly averages something is learned of the rate of improvement of the pasture, and from an average of all records is obtained an approximate value of the average total annual productivity, which is about 1,160 pounds per acre. This figure is obtained by a method that denudes the ground. Stock always get less than this amount.

(2) Records of hay cutting on part of the reserve have been obtained for the past five years on areas varying from 1 to 114 acres. The total area for all seasons from which measurements were obtained was $492\frac{1}{2}$ acres. The average amount of hay obtained is 640 pounds per acre. Three areas, each about an acre in extent, which had the hay cut off for four years in succession, lost in productivity from one-half to three-fourths of what they produced at the start, as the result of continued cutting. The average production of hay on this land is about 70 per cent of the productivity shown by the quadrat collections made on and beside the areas cut over; hence, it is argued that stocking on the basis of an estimated production of more than one-half of the total productivity as obtained from the quadrat measurements would be unwise, since such a policy would tend to lower the carrying capacity below what would be maintenance capacity for the area under stock.

(3) A map is submitted, showing the approximate distribution of the different forage-plant associations of the reserve, and descriptions of the details and possibilities of each are presented. From the quadrat measurements the approximate productivity of each association is obtained. From these figures and the areas of each association a weighted average expression representing the average productivity of the whole reserve is derived. This number, 1,110 pounds per acre, is closely comparable with that obtained as the average of the quadrat measurements alone. Assuming the value of 1,100 pounds per acre as an average total productivity and 50 per cent of that amount as maintenance capacity for the range, then, if the average animal eats the equivalent of 30 pounds of dry feed per day he will need 11,000 pounds in a year, and it will take 10 acres of land to furnish that amount at full productivity, and 20 acres of land at maintenance capacity. Thus we have an average value for carrying capacity equal to 20 acres per head per year, or 32 head per section, for the reserve.

(4) Records of animal-days' feed consumed for a period of five years on about 16 per cent of the best part of the reserve show exactly what this land can do under a certain kind of management. The type of management used tends to make the carrying capacity for this area appear high. The pastured area naturally has the highest carrying capacity of any part of the reserve. The area has probably been slightly overstocked recently. All three of these factors tend to increase the apparent carrying capacity of the area under stock. The figure representing average carrying capacity for $7\frac{1}{4}$ sections (one-eighth of the whole reserve) which have been stocked with cattle is 14.1 acres per head per year, or 45+ head per section. This carrying capacity, for the reasons stated, is considerably above that for the whole range. Just how much too high it is would be very hard to tell. Figures obtained on one of the pastures show that stocking at the average rate of 58 acres per head per year, or 11 head per section, is considerably below the limit of maintenance capacity, since the pasture so stocked is now not noticeably different in condition from adjacent land which has had no stock on it for 11 years.

Miscellaneous data.—Miscellaneous notes on the effects of fire, the effect of protection on the minor relief features of the area, some results of seed sowing, the results of a small amount of sheep grazing, etc., are added, and a few suggestions as to the character of future work are made.

LIST OF PUBLICATIONS RELATING TO THIS SUBJECT.

Range Improvement in Arizona. By David Griffiths. Bur. Plant Indus. Bul. 4. 1901.

Range Investigations in Arizona. By David Griffiths. Bur. Plant Indus. Bul. 67. 1904.

The Reseeding of Depleted Range and Native Pastures. By David Griffiths. Bur. Plant Indus. Bul. 117. 1907.

A Protected Stock Range in Arizona. By David Griffiths. Bur. Plant Indus. Bul. 177. 1910.

The Grazing Ranges of Arizona. By J. J. Thornber. Bul. Ariz. Exp. Sta. 65. 1910.

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BULLETIN No. 368



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 6, 1916

BROWN-ROT OF PRUNES AND CHERRIES IN THE
PACIFIC NORTHWEST.

By CHARLES BROOKS and D. F. FISHER, *Office of Fruit-Disease Investigations.*

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INTRODUCTION.

For several years the growers of the lower Columbia and Willamette Valleys have had severe losses of their prunes and cherries. Among the causes have been a failure of the trees to set a full crop and a lack of keeping quality in the harvested fruit due to brown-rot. Occasional midsummer outbreaks of brown-rot have also occurred.

In the spring of 1914 Mr. M. B. Waite, Pathologist in Charge of Fruit-Disease Investigations, examined some diseased prune blossoms from Vancouver, Wash., and was in correspondence with the growers concerning the cause of the prune trouble. He has furnished the following manuscript note covering these investigations:

With a letter dated April 18, 1914, from Mr. Chapin A. Mills, Vancouver, Clarke County, Wash., addressed to the Department of Agriculture, specimens of spurs and twigs of the Italian prune (*Prunus domestica*), with dead and dying blossoms, were received, with an inquiry as to the cause and remedy for the bad condition of the blossoms, the dropping of the bloom and young fruit, and the widespread failure of the crop to "set" or hold its fruit. A few days later a similar set of specimens was received from the same district, and a number of inquiries, without specimens, reached us from Washington, Oregon, and California, including the Sacramento and Santa Clara Valleys, as to the cause of the failure of the prunes to set their fruit.

NOTE.—This bulletin is intended particularly for the benefit of prune and cherry growers of western Washington and Oregon, but is of interest to growers of these fruits in other sections of the United States. It is also of scientific interest to plant pathologists in general.

A microscopic examination of the blighting blossoms showed them to be infected with the ordinary brown-rot fungus, which for the present may be designated by the name *Sclerotinia cinerea*. The specimens showed that the conidial or "Monilia" form of the fungus had attacked the bloom in various stages, killing some of the buds before they had opened, often penetrating the entire flower and extending down the pedicels. Some of the blossoms had set their fruit, and the young prune had started to develop before the flower was completely killed. In some cases the young fruits were penetrated; in others they were not yet occupied by the fungus, which had partly killed the flower and spread down the pedicel. The conidial form of the fungus was fruiting abundantly over most of the surface of the diseased organs.

An extended correspondence was carried on with the growers during the spring and summer of 1914, in which it was developed that the prunes in that section had been dropping quite badly for several years from causes unknown to the orchardists; that rather cool, rainy weather occurred during blossoming time in 1914—not severe, heavy rains, but continuous damp weather. The prunes "made a good setting, but immediately seemed to stop their growth, and the 'husk' gradually dried and adhered to the prune, finally all falling off." Naturally, the possibility of control of the fungous trouble by early spraying was suggested in the correspondence.

Notwithstanding this very definite evidence that the specimens of prune blossoms received were killed by the brown-rot fungus, it was suggested as not safe to at once conclude that the whole trouble of nonsetting of prunes was due to this fungus, since the same rainy weather which would favor the brown-rot fungus would also interfere with the pollination and fertilization of the fruit. Nutrition factors and general temperature conditions would also be concerned in the problem of prune dropping. It seemed hardly probable that the brown-rot fungus could be charged with all the difficulties, including those of the Sacramento and Santa Clara Valleys in California.

Subsequently, from specimens of partly ripe cherries received from Mr. A. W. Moody, of Vancouver, Wash., with a letter dated July 11, 1914, a serious trouble with the ripening cherries was also identified as caused by the brown-rot fungus.

The brown-rot fungus is well known to be widely distributed on the Pacific coast in the more humid sections near the ocean. It has been studied and figured by the pathologists of California and Oregon, but always on the ripening fruit. The writer saw it on ripe prunes at Vancouver, Wash., in September, 1907, in the district from which these specimens came. The blossom-blight phase of this disease appears not to have attracted attention as a disease of prunes and other stonefruits on the Pacific coast.

BLOSSOM INFECTION OF PRUNES.

Blossom infection of brown-rot on cherries in New York was reported by Arthur¹ as early as 1885, and a blossom blight of peaches in Delaware was described by Smith² a few years later.

In the summer of 1913 the junior writer obtained information in regard to a peculiar and severe early drop of prunes in Clarke County, Wash., the effects reported being very similar to those of the Monilia blossom blight of the peach as he had observed it in the East. The following summer he made a visit to the section mentioned to study the prune situation. The data collected showed that the prune orchards had again suffered from a severe blossom blight and that the

¹ Arthur, J. C. Rotting of cherries and plums. In N. Y. State Agr. Exp. Sta., 4th Ann. Rpt., 1885, p. 230-285. 1886.

² Smith, Erwin F. Peach rot and peach blight. In Jour. Mycol., vol. 5, no. 3, p. 123-134. 1889.

——— Peach blight. In Jour. Mycol. v. 7, no. 1, p. 36-38, 2 pl. 1891.

conditions were such as to indicate that the brown-rot organism was an important factor in the case.

In the spring of 1915 the prune orchards in the vicinity of Vancouver, Wash., were kept under close observation, and a record was made of orchard and weather conditions. March 28 and 30 were fair days, but with these exceptions it rained almost continuously from March 24 to April 8. The trees were in full bloom on March 23, and on April 5 the blossoms were falling. On the latter date there was no evidence of typical blossom blight as it usually occurs in eastern sections, but many of the calyx cups were turning brown on the under side where drops of water had hung, and the margins of the sepals were often similarly affected. On April 8 some of the young fruit was turning yellow and dropping, apparently from lack of fertilization of the blossoms. At this time the browning of the calyxes had become much more serious, involving in some cases more than three-fourths of the crop of the unsprayed trees. It was much more abundant on the lower than on the upper branches and seemed to be as common on the fertilized as on the unfertilized fruit. In some cases the browning spread down the pedicel, the fruit often turning back on its stem; in others it involved most of the calyx, the young fruit separating readily from it. (Pl. I, figs. 4, 5, and 6.) The latter condition was more common on the fertilized blossoms. When placed in a moist chamber, the affected fruit developed an abundant growth of *Monilia*, the conidial stage of *Sclerotinia cinerea* (Bon.) Wor.¹

On April 12 a heavy drop was taking place, both of the unfertilized and the fertilized but infected fruit. At this time the fertilized fruit could be readily distinguished from the apparently unfertilized by its enlarged ovary, its lengthened pedicel, and its darker green color.

The brown-rot fungus produces two distinct types of spores—one, the *Monilia* or summer form, which gives the characteristic mouse-colored appearance to the rotting fruit; the other, the mature or perfect stage, in which the spores are borne on the upper surface of cup-shaped fruiting bodies, known as apothecia, that develop from the mummied prunes.

On April 2 apothecia were evident under the trees on the diseased prunes of previous seasons. By April 8 they had developed in large numbers, 30 to 40 clusters often being found on the ground under one tree. (Pl. I, fig. 3.) On the latter date many of the apothecia had shed their spores, and by April 12 they were disappearing. Most of the apothecia came from prunes near the surface of the soil, and while some had unusually long stalks none could be found coming from a greater depth than 3 or 4 inches.

¹ Matheny, W. A. A comparison of the American brown-rot fungus with *Sclerotinia fructigena* and *S. cinerea* of Europe. In Bot. Gaz., v. 56, no. 5, p. 418-432, 6 fig. 1913.

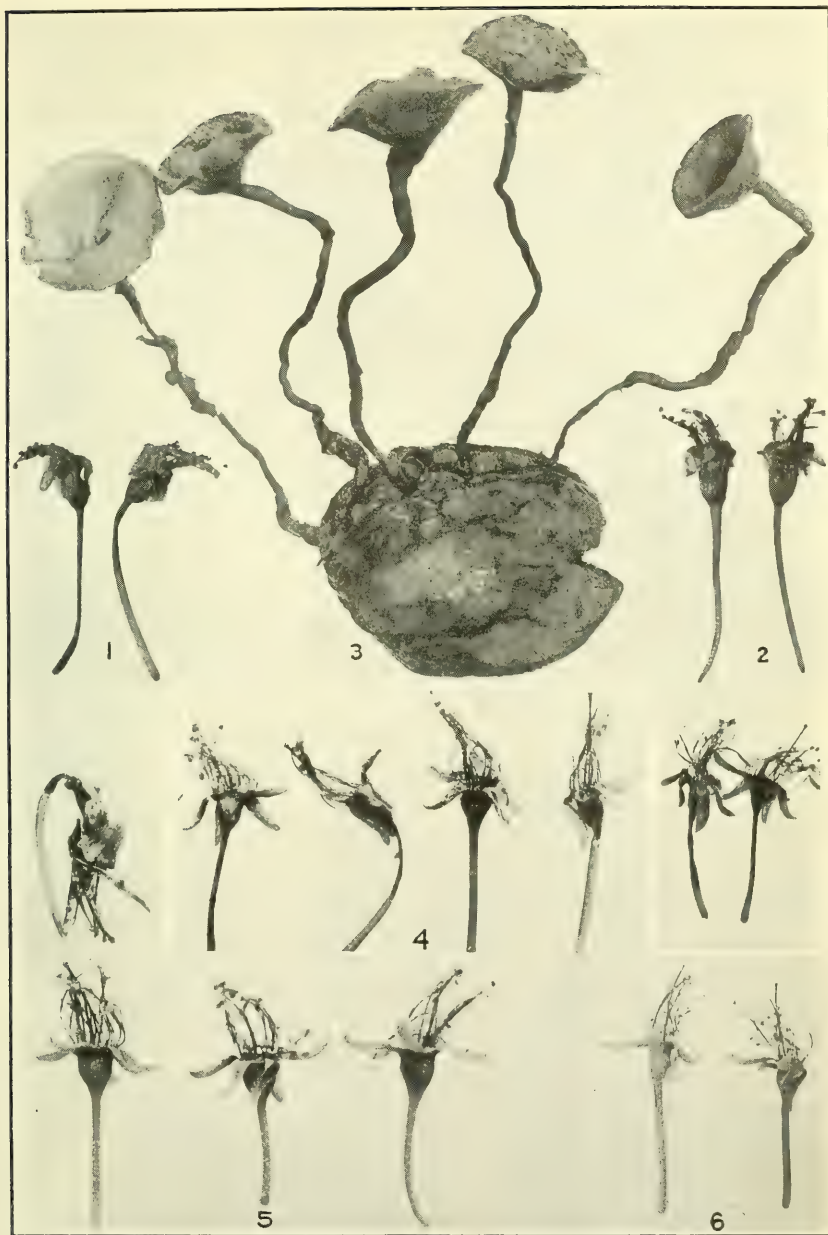
A comparison of the time of the development of the apothecia with the dates of infection on the prunes furnishes strong evidence that the apothecia were the source of infection. Further evidence of this may be found in the fact that *Monilia* could not be found in fruiting condition on cankered limbs, although a very careful search was made. The fact that the disease was much worse on the lower limbs than in the tops of the trees might be taken as further evidence that the infection was from below, but moisture conditions may have been of importance in producing this difference. It was also found that in orchards where early spring plowing and cultivation were practiced there was little or no calyx infection of brown-rot. While soil variations and the effects of culture upon the general vigor of the tree must not be lost sight of, there is little doubt that the deterrent effect of the cultivation upon the development of the apothecia was of direct value in the prevention of the disease.

The wind is probably the important agent in spreading the spores of the fungus. Insects may be concerned to some extent in this distribution, but are of greater importance on account of the punctures they produce on the fruit, these injuries furnishing an entrance point for the fungus. Among the insects, the fruit-tree leaf syneta (*Syneta albida* Leconte) is probably of importance, as it was present in great numbers during the early part of the season, feeding on both fruit and foliage and causing much damage.

SPRAYING EXPERIMENTS.

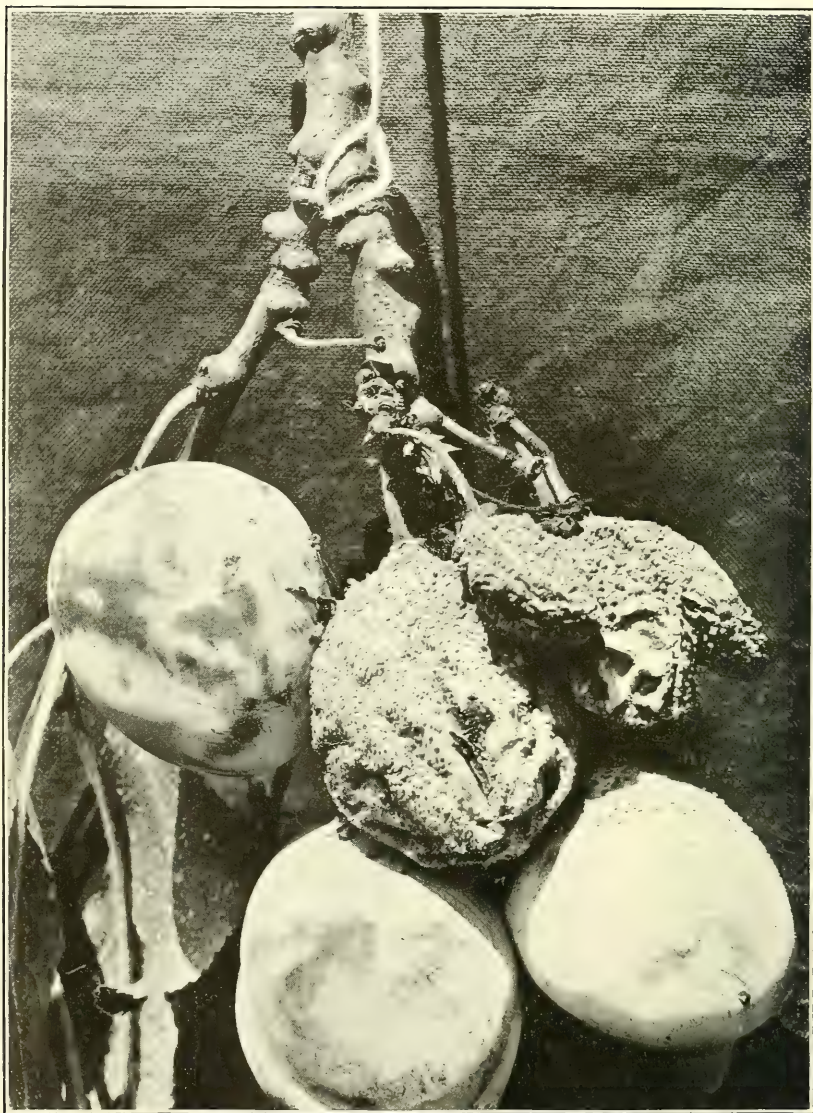
Further evidence of the importance of the blossom infection was obtained from the spraying experiments of the season of 1915. The work was carried on in the orchards of A. W. Moody, at Felida, Wash. The first spraying was made on March 17, when the buds were beginning to swell, a second on March 24, when the cluster buds were open and the blossoms showing white, and a third on April 8, when the petals were practically all off. The first application was made with 4-4-50 Bordeaux mixture; the later ones with 8-8-50 self-boiled lime-sulphur. No spreader or sticker was added in any of these applications. At the time of the third spraying but little evidence of the second could be found on the trees. The two weeks of almost constant rain had apparently washed most of it off. It was evident that something should have been added to the fungicides to increase their adhesive qualities. It was also evident from the time the infections appeared that better results would have been secured if the second and third applications had been nearer together.

The heavy infection described, which had taken place previous to the third spraying, made it plain that it was then too late to secure the best results. Notes taken May 10 to 15, however, showed that the spraying had saved a considerable percentage of the crop. At that



CHERRIES AND PRUNES AFFECTED WITH BROWN-ROT.

FIG. 1.—Black Republican cherries affected with brown-rot, collected at Salem, Oreg., April 13, 1915. FIG. 2.—Same as figure 1, but not affected with brown-rot. FIG. 3.—Italian prune mummy bearing five apothecia, collected at Felida, Wash., April 9, 1915. This prune was buried to a depth of about 2 inches and the apothecial cups were borne just above the surface of the soil. FIG. 4.—Italian prunes affected with brown-rot, collected at Felida, Wash., April 9, 1915. FIG. 5.—Same as figure 4, but not affected with brown-rot. FIG. 6.—Same as figure 5, but these are blossoms that were yellow and apparently unpollinated. Note the small size of the ovaries in comparison with those of figures 4 and 5. All the photographs reproduced above were taken from specimens that had been preserved in formalin.



ITALIAN PRUNES AFFECTED WITH BROWN-ROT.

Photographed when the fruit was beginning to color, August 11, 1915.

time the number of fruit spurs that had borne blossoms and the number of prunes still remaining were counted on representative branches from the various plats. The results obtained are shown in Table I.

TABLE I.—*Prune spraying experiments at Felida, Wash., in March and April, 1915.*

Plat.	Sprayings.	Prunes per 4,000 spurs.	Plat.	Sprayings.	Prunes per 4,000 spurs.
No. 2.....	First, second, and third..	292	No. 9.....	First and third.....	143
No. 3.....	First and second.....	243	No. 10.....	None.....	69
No. 7.....	Second.....	369	No. 6.....	do.....	86

These results show that the sprayed trees had retained from two to five times as much of their fruit as the unsprayed ones. A comparison of the set of fruit on the different sprayed plats would indicate that the second spraying was the most important one, but that the third was also very valuable. A study of the final crop from the orchard, as given later, shows that the average yield on the nine plats that received an application of self-boiled lime-sulphur, either in the second or third spraying or both, was more than two and a half times as great as that from plats 6, 10, and 11, which received no early spraying.

If an adhesive had been added to the fungicide in the second application, there is little doubt that the results would have been much more striking, for, as already mentioned, much of this spray had been washed off by rains before the third application was made, thus leaving but poor protection during the most critical period of infection.

The above data show very conclusively that the blossom blight was an important factor in the poor set of fruit obtained in 1915. Observations on the calyx browning and on the fruit drop in several different sections of southwestern Washington and also in the orchards near Salem, Oreg., indicated that the conditions described for Vancouver were of general occurrence in the prune orchards of the lower Columbia and Willamette Valleys.

FRUIT ROT OF PRUNES.

The orchard observations were continued throughout the summer, and records were kept of weather conditions and the prevalence of disease. Frequent showers occurred during the last three weeks of May, but the weather during the latter part of the summer was comparatively dry, the rainfall being considerably below the average for the season.

The occurrence of brown-rot was noted on some of the plats in the latter part of May, but there was no serious outbreak at any time during the summer.

The spraying experiments were continued throughout the season. In addition to the dormant spray of March 17, the bud spray of March 24, and the calyx spray of April 8, a fourth application was made May 1 to 4, a fifth May 29, a sixth June 14, and a seventh August 6, about a month before harvest.

The following spray materials were used:

- F1. Bordeaux mixture, 4-4-50.
- F2. Same as F1, but with 2 pounds of resin-fishoil soap added.
- F3. Self-boiled lime-sulphur, 8-8-50.
- F4. Same as F3, but with 2 pounds of resin-fishoil soap added.
- F5. Same as F3, but with three-fourths pound of dry powdered arsenate of lead added.
- F6. Commercial lime-sulphur, 1½ to 50.
- F7. Commercial lime-sulphur, 1 to 50.
- F8. Same as F6, but with 2 gallons of flour paste added.

The flour paste was made by boiling 1 pound of flour in 1 gallon of water about half an hour, until a thick paste was formed. The resin-fishoil soap was purchased on the market in the East. It can not be readily obtained on the Pacific slope, but may be made up as follows:

Resin.....	5 pounds.
Potash lye, such as is sold for washing purposes.....	1 pound.
Fish oil.....	1 pint.
Water.....	5 gallons.

The resin is dissolved in the oil by heating in a large kettle. After this has partially cooled, the potash is added, the mixture being slowly stirred and carefully watched to prevent its boiling over. A part of the water is now added and the boiling continued till the mixture will dissolve in cold water. This will require about one hour. The remainder of the water is then slowly added and the mixture thoroughly stirred. The resin-fishoil soap was found very valuable in making the spray adhere to the fruit. It can not be used with commercial lime-sulphur.

It was found that the fruit was covered better when a driving type of nozzle was used. None of the sprays used caused any injury. The second orchard adjoined the first. The trees were younger and had borne but a very light crop the previous year. Apothecia were of rare occurrence in this orchard in the spring.

The prunes were harvested September 7 to 10. A count was made of the entire prune crop of the five trees of each plat. A crate of sound fruit was packed from each of the more important plats, the packed samples being stored in a noncooled orchard warehouse until September 14 and then shipped by express to Wenatchee, Wash. The figures in the last column of Table II show the percentage of brown-rot that had developed 12 days after harvesting.

TABLE II.—*Spraying for brown-rot of prunes at Felida, Wash., during the season of 1915.*

Plat.	Sprayings. ¹							Yield (number of prunes).	Brown-rot (per cent).	
	1st.	2d.	3d.	4th.	5th.	6th.	7th.		At har- vest.	After 12 days' storage.
First orchard:										
No. 1.....	F1	F3		F4		F4	F4	723	0.27	
No. 2.....	F1	F3	F3	F4		F4	F4	1,410	.78	2
No. 3.....	F1	F3				F4	F4	1,636	.48	6
No. 4.....	F1	F3		F4			F4	1,761	1.08	15
No. 5.....	F1	F3		F4		F4		3,582	.19	1
No. 6.....								1,150	3.39	41
No. 7.....		F3		F4		F4	F4	1,985	.15	3
No. 8.....		F3		F3		F3	F3	2,911	.28	8
No. 9.....	F1		F3	F3		F3	F3	1,608	.12	3
No. 10.....				F4		F4	F4	720	.28	
No. 11.....						F4	F4	493	2.43	
No. 12.....	F1		F5	F5		F5	F5	2,582	.27	2
No. 13.....	F1		F1	F2		F2	F2	2,684		
No. 14.....	F1		F1	F1		F1	F1	2,519	1.15	
No. 15.....	F1	F6		F6		F6	F6	1,804	.28	12
No. 16.....	F1		F7	F7		F7	F7	2,392	1.05	9
Second orchard:										
No. 17.....	F1				F2	F2	F2	4,391	4.16	51
No. 18.....	F1				F8	F8	F8	5,633	4.67	25
No. 19.....	F1				F4	F4	F4	5,295	3.29	37
No. 20.....	F1			F1				4,673	5.35	95

¹ The symbols, F1, F2, etc., refer to the spray formula used, as explained on p. 6.² Fruit shriveled from an unknown cause.

The favorable effect of the early applications on the yield has already been discussed. The amount of brown-rot at harvest time was not large on any of the plats, but in the first orchard there was more than nine times as much on plat 6, which was unsprayed, as the average amount on the nine plats which received both early and late applications of self-boiled lime-sulphur, the former having 3.39 per cent of brown-rot, the latter 0.36 per cent. In the second orchard, plat 20, which received no late spray, had nearly twice as much brown-rot as plat 19, which received late applications with the above fungicide. The contrasts on the stored fruit were still more striking, because of the larger amounts of the disease. The prunes from the unsprayed plat of the first orchard had developed 41 per cent of brown-rot, while the average from the sprayed trees mentioned above was 5 per cent. In the case of the second orchard, the unsprayed fruit had 95 per cent of brown-rot, while that which received a late spraying with self-boiled lime-sulphur had 37 per cent and that sprayed with commercial lime-sulphur 25 per cent.

In some of the neighboring orchards where no sprayings were made, more than three-fourths of the crop was affected with brown-rot at harvest time (Pl. II). In such cases the fruit that was harvested was handled with great difficulty, as it would scarcely be in a usable condition if allowed to stand over night at the drier.

It is evident that spraying is not only of great value in securing a yield, but also in the harvesting operations, and that if the fresh prunes are to be marketed it is absolutely indispensable.

In the summer of 1915 the rainfall at Portland, Oreg., 15 miles distant, was below the average and very decidedly so in March, April, and September, the months in which the most critical periods of infection apparently occur. It is the number of damp days rather than the inches of rainfall that actually determines the opportunity for infection, but in this respect also the season of 1915 was not unusually favorable to the disease. It seems probable, therefore, that spraying and other remedial measures would be of even greater importance in other years than the results in 1915 show for that season.

SUMMARY AND CONCLUSION FOR PRUNES.

The above observations and results indicate that in such seasons as that of 1915 the brown-rot problem is one of great importance to the prune industry in the more humid sections of the Northwest. It has been shown that the apothecia which develop from the fallen prunes are the probable source of the blossom infection. Fall plowing and early spring cultivation ahead of the blossoming period have apparently helped to prevent the disease by interfering with the development of the apothecia.

The early applications of spray were washed off, showing the importance of the addition of a sticker, but even with rather unsatisfactory conditions spraying has given fairly good results. The plats given both early and late sprayings with self-boiled lime-sulphur set from two to five times as much fruit as the unsprayed ones, gave two and a half times as large a yield, and had one-ninth as much brown-rot on the harvested and one-eighth as much on the stored prunes. Self-boiled lime-sulphur and Bordeaux mixture have both given good results, but the former has seemed somewhat more satisfactory. Bailey has also reported good results from the use of these fungicides on prunes.¹

The sticking and spreading qualities are greatly improved by the addition of 2 pounds of resin-fishoil soap to each 50 gallons of the mixture.

Several years' results will be necessary as a basis for any final recommendations, but in so far as the season of 1915 was typical the following schedule of spraying may be suggested:

The first application just before the blossoms open.

A second just after the petals have fallen.

A third three to four weeks later, just after the husks have fallen.

A fourth about four weeks before harvesting.

¹ Bailey, F. D. Experimental spraying of prunes for control of brown-rot. *In* Oreg. Agr. Exp. Sta., 2d Bien. Crop Pest and Hort. Rpt. 1913-14, p. 241-244. 1915.



IMMATURE ROYAL ANN CHERRIES AFFECTED WITH BROWN-ROT.

Photographed May 25, 1915.

The first and fourth applications have been especially important the past season.

BLOSSOM INFECTION OF CHERRIES.

Observations made near Vancouver, Wash., on April 8 and in the vicinity of Salem, Oreg., on April 13 showed that there had been a blossom infection of cherries similar to that already described on prunes (Pl. I, figs. 1 and 2). On the latter date *Monilia* was fruiting luxuriantly on the blighted cherries. It appeared that most of the infection had taken place after the petals had fallen and before the fruit had had a chance to push through the husk. Black Republican cherries seemed especially badly infected. Estimates made on April 13 indicated that on this variety fully 90 per cent of the blossoms were infected with *Monilia*, and in many orchards of other varieties at least 75 per cent were similarly infected. A grower near Felida, Wash., sprayed some of his cherry trees while they were in full bloom, using lime-sulphur solution diluted 1 to 30. He delayed the spraying of the others until the calyx browning had begun to appear and then applied the same spray he had used earlier. Counts made on April 8 of representative branches from each lot of trees showed 9 per cent of infected fruit in the former case and over 40 per cent in the latter. Spraying trees in full bloom is not to be recommended, but the results show the value of early spraying.

BROWN-ROT OF CHERRIES.

Spraying experiments for the control of brown-rot on the fruit were carried on in the orchard of L. T. Reynolds, of Salem, Oreg. The work was begun late in the season. The first application was made on May 7 and 8, when the fruit had begun to color, and a second on June 1, when the fruit was approaching maturity. The latter application was delayed for nearly a week on account of rain.

Plat 1 received Bordeaux mixture, 2-4-50, plus 2 pounds of resin-fishoil soap; plat 2, commercial lime-sulphur, 1 to 50; plat 3, self-boiled lime-sulphur, 8-8-50, plus 2 pounds of resin-fishoil soap; and plat 4 was unsprayed.

No injury resulted from the use of any of the fungicides. The Royal Ann cherries were picked on June 17 and the Black Republicans on June 24. A regular 10-pound box of sound cherries was packed from each plat and placed in cold storage at 40° F. until June 27, and the fruit was then shipped by express to Wenatchee, Wash. Notes on the Royal Anns were taken on July 2 and on the Black Republicans on July 6. The former were thus in cold storage at 40° F. for 10 days and at air temperature for 6 days, the latter in cold storage for 3 days and at air temperature for 10 days. Table III gives the results obtained.

TABLE III.—*Spraying cherries for the control of brown-rot at Salem, Oreg., during the season of 1915.*

Plat.	Treatment, if any.	Brown-rot (per cent).			
		Royal Ann.		Black Republican.	
		At picking.	After storage.	At picking.	After storage.
No. 1.....	Bordeaux mixture.....	0.17	11	0.03	7
No. 2.....	Lime-sulphur.....			.05	8
No. 3.....	Self-boiled lime-sulphur.....	.25	14	.07	2
No. 4.....	Unsprayed.....	.67	55	.03	18

There was not enough brown-rot evident on any of the plats at picking time to make the contrasts of any great interest. (Pl. III.) After the severe storage tests the effects of spraying were more evident, the fruit from the self-boiled lime-sulphur plat having only one-fourth as much brown-rot as that from the unsprayed plat in the case of the Royal Anns and one-ninth as much in the case of the Black Republicans. With the Royal Anns better results were secured with Bordeaux mixture than with the self-boiled lime-sulphur. The sprayed fruit held up much better at the local canneries than the unsprayed fruit.

SUMMARY AND CONCLUSION FOR CHERRIES.

While the work on cherries has not been carried out as fully as was desired, it seems evident that the *Monilia* blossom blight was the cause of serious losses in the Willamette Valley in the season of 1915 and the brown-rot of the fruit the cause of considerable loss at the canneries and heavy losses in the shipping of fresh fruit. No early sprayings were made, and therefore no results were obtained on the effect of spraying upon the blossom infection. The brown-rot at the canneries and in storage has been greatly reduced by late applications of Bordeaux mixture and self-boiled lime-sulphur. It seems probable that a treatment for cherries similar to that outlined for prunes would give satisfactory control of both the blossom infection and the later brown-rot attacks on the fruit.



BULLETIN No. 369

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief



Washington, D. C.

PROFESSIONAL PAPER

May 26, 1916

BACTERIA IN COMMERCIAL BOTTLED WATERS.

By MAUD MASON OBST, *Bacteriological Chemist.*

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INTRODUCTION.

During the last six years from 1 to 17 samples of bottled waters from each of 110 American springs and from 57 sources in foreign countries have been examined in the Bacteriological Laboratory of the Bureau of Chemistry.¹ A comparative study of the results obtained should, therefore, contribute toward the formation of an opinion as to the freedom from contamination which we have a right to expect and to demand in the case of this product. These bacteriological analyses have been brought together and tabulated; and the results of this study have been considered to determine whether the standard adopted by the United States Public Health Service² for water on trains could be fairly applied to bottled waters, or whether some other standard would be more just.

A questionnaire was also sent out to a number of bacteriologists who have been associated with sanitary and allied problems. This questionnaire was arranged primarily to learn the attitude of a widely distributed group of workers in regard to bacterial tolerance in bottled waters. Of the 49 correspondents who have replied, 8 had not worked upon water sufficiently to feel competent to express any opinion. The remaining 41 replies are summarized as follows: Eight (19.8 per cent) stated that to them the term "bottled water" implied an unwritten guaranty of absolute purity; five (12.1 per

¹ Examinations were made by various members of the Bacteriological Laboratory, including Dr. Geo. W. Stiles, Minnie Jenkins, Carleton Bates, Ruth C. Greathouse, and the author.

The author wishes to acknowledge the valuable assistance rendered by Dr. Charles Thom in the preparation of this paper.

² U. S. Public Health Reports, 1914, p. 2959. (Not more than one out of five 10 cc portions shall show gas.)

cent) desired no rigid standard; only one desired a standard of no *B. coli* in 10 cc quantities; thirty-five (85.4 per cent) desired to apply the Hygienic Laboratory standard or one more rigid; eight (19.8 per cent) would tolerate no *B. coli* in bottled waters; one of the five bacteriologists desiring no rigid standard considered water to be suspicious if three 10 cc portions show *B. coli*.

We have a right to demand that bottled water shall first of all be clean. Whatever other qualities it may claim or offer are secondary to cleanliness. In a study, therefore, of the bacteria found, we have a right to consider them not only as possible evidences of danger to health but as indices of conditions in the bottling room for which the operator is clearly responsible.

SIGNIFICANCE OF BACTERIA IN POTABLE WATERS.

It is understood that natural waters may contain bacteria which multiply in the presence of very small amounts of organic matter. Bacteriologists who have worked with distilled water are familiar with the micrococci which multiply rapidly therein when the percentage of organic material is extremely low. The presence, therefore, of a large number of organisms in waters which have been bottled for several days or weeks has little significance unless the characters of these organisms are more or less definitely known.

The presence of *B. coli* in large numbers in waters is universally considered as an indication of the possible presence of its dangerous associates. The conditions under which waters are bottled and held and the mineral substances present may, in some cases, exert influences upon the multiplication of *B. coli* differing slightly from the effect of surface or well waters in nature. Preliminary studies in this laboratory indicate an immediate decrease instead of any possible increase of *B. coli* in freshly inoculated bottles of certain spring waters.¹ Houston² found that *B. coli* disappeared in stored water from the River Lea. Dunham³ observed that distilled water enriched with either hay infusion or nutrient broth (1 cc in 1 liter) and inoculated with over 20,000 *B. coli* showed a marked reduction of the total number of *B. coli* at the end of 24 hours. He also reported that sterile water inoculated with pollution from ordinary soil does not show an appreciable number of *B. coli*.

It may, therefore, be assumed that bottled waters in which *B. coli* are found in appreciable numbers contained approximately all of those *B. coli* (if not more) when they left the springs or bottling

¹ Browne, W. W. (Jour. Infect. Dis., v. 17, No. 1, 1915, pp. 72-78) finds multiplication of *B. coli* in stored water, but an analysis of his experiments shows that the water used was so enriched as to be no longer comparable to stored spring waters.

² Houston, Reports on Research Work, Metropolitan Water Board, London, 1907.

³ Dunham, E. K., Value of bacteriological examination of water from a sanitary point of view, Jour. Amer. Chem. Soc., v. 19, No. 8, 1897, p. 591.

houses. It is reasonable also to assume that when people pay from 2 cents to \$30 per gallon for bottled water they expect to obtain a pure, or at least a safe water. Whipple¹ has defined a "pure" water as one which is "free from bacteria or other organisms which are liable to cause disease, and also free from *B. coli*."

INSPECTION OF SPRINGS.

The ultimate test of the fitness of a particular water for sale lies in its condition at the spring. When contaminations are found in the bottled article, the determination of responsibility for the condition found calls for inspection at every stage of its handling. Such inspections of springs have been made from time to time, usually resulting in locating the source of trouble. The results of the inspection of three springs are included in Tables I, II, and III. These illustrate certain typical sources of pollution. In spring No. 1, insufficient coverings over the spring evidently permitted the entrance of a rotten lemon or orange, containing the mold *Penicillium italicum*, a short time previous to the collection of these samples. This mold can not exist long in water, and is practically never found except on decaying citrus fruits. The actual inspection of this spring and statements by the people of the vicinity disclosed the fact that freshets would cause the water in the creek flowing past to back through a swimming pool and into the spring. Inadequate care was also apparent in the method of cleaning and rinsing the bottles before they were filled. These bottles, as were those used at spring No. 3, were rinsed with polluted water just before filling. (See Table III.) The water in spring No. 2 was undoubtedly grossly polluted at times from the creek which flowed past. A culture of *B. paratyphosus* B was obtained from a shipment of bottled water from this spring four months prior to the inspection.

It is not always possible, however, to locate the source of contamination at the spring even by several inspections. One such spring is still under observation. This spring is on high land well removed from farm buildings and large streams of surface water. Its water is highly mineralized and at its source contains *B. coli* in 1 cc or 0.1 cc quantities. It is said that the water is boiled and the bottles sterilized before the bottling; yet 88 out of 96 bottles purchased at retail stores have been found to contain *B. coli* in 10 cc quantities, and 64 out of 96 in 1 cc quantities. The *B. coli* found were identified in all instances as belonging to the *communis* and *communior* groups. Evidently the survey has been incomplete in some essential point.

Naturally carbonated waters occasionally contain large numbers of organisms. In general, however, artificially carbonated waters

¹ Whipple, Geo. C., Value of pure and wholesome water, Biol. studies of the pupils of W. T. Sedgwick, June, 1906.

were found to contain no *B. coli* in 10 cc quantities and very low total counts at both temperatures of incubation. The total counts very seldom were above 50 per cc, and often were less than 10 per cc.

In certain instances legal actions have been brought against companies preparing and selling bottled waters when the waters examined have contained an excessive number of organisms, including *B. coli*. These companies having been thus impressed with the necessity of producing a clean commercial product have responded by placing on the market later consignments from which no *B. coli* were isolated in 10 cc quantities from 12 or more bottles. Repeated examinations of water from many springs have failed to show any *B. coli* in 10 cc quantities.

EXAMINATION OF COMMERCIAL BOTTLED WATERS.

The methods employed in making these bacterial examinations were those prescribed from year to year by the committee on water analysis of the American Public Health Association. The high-temperature counts have always been made on plain agar after incubation at 37° C.; but the earlier low-temperature incubations were made on agar at 25° C., instead of on gelatin at 20° C., as during the last two years. Dextrose broth, lactose bile, and lactose broth have been used at different times for the preliminary tests for *B. coli*; but in nearly every instance, when reported present, *B. coli* have been isolated. Many of these have been verified by testing special dextrose cultures with methyl red, as recommended by Clark and Lubs.¹ A summary of all these examinations follows:

Of 110 domestic springs (see Table IV)—

- 47 (43 per cent) contained no *B. coli* in 10 cc quantities.
- 63 (57 per cent) contained *B. coli* in 10 cc quantities.
- 61 (55 per cent) contained *B. coli* in 5 cc quantities.
- 59 (53 per cent) contained *B. coli* in 1 cc quantities.²
- 49 (44 per cent) contained *B. coli* in 0.1 cc quantities.
- 31 (28 per cent) contained *B. coli* in 0.01 cc quantities.
- 10 (9 per cent) contained *B. coli* in 0.001 cc quantities.³

Sixty-nine (62 per cent) gave counts of less than 100 per cc on one or more bottles after incubation at 37° C. for two days.

Eighteen (16 per cent) gave average counts of less than 100 per cc on six or more bottles at 37° C.

Fourteen (12 per cent) gave no counts of less than 1,000 per cc on six or more individual bottles.

The highest average count on all samples from any one spring was 191,238.

¹ Clark and Lubs, The differentiation of bacteria of the Colon-aerogenes family by the use of indicators Jour. Infect. Dis., v. 17, No. 1, 1915, p. 160.

² Any potable water supply containing *B. coli* in 1 cc quantities is considered suspicious by health departments and is at once investigated.

³ Water containing *B. coli* in 0.001 cc quantities is too suggestive of dilute sewage to be accepted by anyone.

Of 57 foreign springs (see Table V)—

- 29 (51 per cent) contained no *B. coli* in 10 cc quantities.
- 28 (49 per cent) contained *B. coli* in 10 cc quantities.
- 25 (45 per cent) contained *B. coli* in 5 cc quantities.
- 21 (37 per cent) contained *B. coli* in 1 cc quantities.¹
- 16 (28 per cent) contained *B. coli* in 0.1 cc quantities.
- 8 (14 per cent) contained *B. coli* in 0.01 cc quantities.
- 2 (3 per cent) contained *B. coli* in 0.001 cc quantities.²

Forty (70 per cent) gave counts of less than 100 on one or more bottles after incubation for two days at 37° C.

Twenty-five (44 per cent) gave average counts of less than 100 per cc at 37° C.

The highest count shown at 37° C. was 37,000 per cc. This sample gave an average count of 16,000 per cc, and *B. coli* were found in one-third of the bottles examined in 5 cc quantities.

Two imported waters bearing on their labels the words "bacteriologically pure" gave the following results:

Sample No. 1; six bottles examined—

Lowest number of organisms per cc developing on gelatin at 20° C.....	700
Average number of organisms per cc developing on gelatin at 20° C.....	2,450
Lowest number of organisms per cc developing on agar at 37° C.....	300
Average number of organisms per cc developing on agar at 37° C.....	1,250
4 bottles contained <i>B. coli</i> in 10 cc quantities.	
4 bottles contained <i>B. coli</i> in 5 cc quantities.	
4 bottles contained <i>B. coli</i> in 1 cc quantities.	
2 bottles contained <i>B. coli</i> in 0.1 cc quantities.	

Sample No. 2; seven bottles examined—

Lowest number of organisms per cc developing on gelatin at 20° C.....	120
Average number of organisms per cc developing on gelatin at 20° C.....	9,410
Lowest number of organisms per cc developing on agar at 37° C.....	40
Average number of organisms per cc developing on agar at 37° C.....	482
6 bottles contained <i>B. coli</i> in 10 cc quantities.	
5 bottles contained <i>B. coli</i> in 5 cc. quantities.	
5 bottles contained <i>B. coli</i> in 1 cc quantities.	
5 bottles contained <i>B. coli</i> in 0.1 cc quantities.	
3 bottles contained <i>B. coli</i> in 0.01 cc quantities.	

Among the organisms which have been isolated from the above samples are: *B. coli*, *B. cloacæ*, *B. mycoides*, *B. paratyphosus* B, *B. aerogenes*, *B. aurantiacus*, *M. citreus*, *B. maritimum*, *B. ovale*, *B. prodigiosus*, *B. fluorescens liquefaciens*, *B. fluorescens non-liquefaciens*, *B. subtilis*, and long-chain streptococci.

Molds of the genera *Trichoderma*, *Penicillium*, *Cladosporium*, *Citromyces*, *Fusarium*, *Actinomyces*, and *Sporotrichum* were identi-

¹ Any potable water supply containing *B. coli* in 1 cc quantities is considered suspicious by health departments and is at once investigated.

² Water containing *B. coli* in 0.001 cc quantities is too suggestive of dilute sewage to be accepted by anyone.

fied.¹ Without attaching too much significance to the occurrence of any of these forms, it may be remarked that *Actinomyces* and *Sporotrichum* are both large ill-defined groups, some of whose members are pathogenic to man as well as to other animals. A large number of spores of a species of *Actinomyces* culturally resembling the pathogenic form were found in one imported water. Similarly, *Sporotrichum* in large numbers was found in another water as taken in the market and as taken directly from the spring three months later. While proving nothing, such observations do not add to the attractiveness of such waters. The other genera listed are regularly found in soil and in decaying vegetable matter. Sufficient to say, they are not indicative of cleanliness.

CONCLUSIONS.

Bottled water for table use should either be actually sterile or should comply with a strict standard as to the number of *B. coli* tolerated.

No water should be permitted to be sold which is contaminated at the source in any manner.

Inspection of springs and bottling establishments together with the analysis of official samples indicates that ignorance of proper precautions, carelessness, and neglect, are fully as large factors in the contaminations found as are impurities actually present in the springs.

The numbers of *B. coli* in official samples collected in the market may be safely assumed to be less rather than greater than the numbers in the freshly bottled stock.

The data as summarized show the need of improvement in the bacteriological condition of many of the brands of bottled water to be found in the market. Careful consideration of cases to which special study has been given shows that there are some springs used for the production of commercial bottled waters which should not be so used. It is evident that the presence of serious and unremovable contamination should shut the water of a spring permanently from the market. Such contamination could easily be ascertained before a water business is established. In other cases, the contaminations found are clearly those of manipulation. Before a person undertakes to operate a water business he should be prepared both in equipment and in operating knowledge to turn out a product free from contamination. This is demonstrated to be commercially possible, without burdensome restrictions, by the number of firms already marketing water free from contamination. It is equally evident in the ability of other firms to produce clean water after the need of doing so has been emphasized by court action.

¹ Identifications were made by Dr. Charles Thom, of the Bureau of Chemistry.

The results clearly show that bottled waters can be made to conform to the requirements of the United States Public Health Service for drinking water furnished upon trains; that is, that not more than one 10 cc sample out of five should show the presence of *B. coli*.

TABULATED DATA.

TABLE I.—Results of the bacteriological examination of water collected from spring No. 1.

Description of sample.	Colonies of organisms per cc developing after—			Smallest quantity in which were found—		
	2 days' incubation on nutrient agar at 37° C.	4 days' incubation on nutrient gelatin at 20° C.		<i>B. coli</i> .		Molds.
		Total count.	Liquefiers.	At time of collection.	2 days after collection.	
"Clean" bottle rinsed with 100 cc sterile water.....	1,000,000	1,400,000	17,000	cc. 0.1	cc. 0.01	cc.
Do.....	900,000	540,000	800	.1	1.0	.....
"Dirty" bottle rinsed with 100 cc sterile water.....	700,000	1,100,000	120,000	.01	.001	.....
Do.....	1,000,000	1,400,000	59,000	.01	.001	.....
16 caps rinsed with 70 cc sterile water.....	4,800	700	18	1.0	5.0	.....
Water used for washing and rinsing bottles.....	790,000	400,000	18,000	.1	.01	.....
Do.....	840,000	1,000,000	90,000	.1	.1	.....
Water from bottling spring.....	3,000	48,000	1,000	(¹)	(¹)	0.001
Do.....	4,500	38,000	1,000	(¹)	(¹)	.001
Water from creek 100 feet from bottling spring.....	410,000	900,000	10,000	.01	.001	.....
Water from swimming pool, after use by 25 people.....	.....	.....	.....	.01	.....	.....
Water from swimming pool, after use by 170 people.....	.....	.....	.....	.001	.....	.....
12 bottles collected after inspection; average results.....	126,000	152,400	5,150	2.001	.....	.001

¹ No *B. coli* were present in 10 cc quantities.

² This determination was made at the time the sample was received at the laboratory.

TABLE II.—Results of the bacteriological examination of water collected from spring No. 2.

Description of sample.	Colonies of organisms per cc developing after—			Smallest quantity in which were found—		
	2 days' incubation on nutrient agar at 37° C.	4 days' incubation on nutrient gelatin at 20° C.		<i>B. coli</i> .		Molds.
		Total count.	Liquefiers.	At time of collection.	2 days after collection.	
"Clean" bottle rinsed with 100 cc sterile water.....	280,000	800,000	800	cc. 0.1	cc. 1.0	cc.
Do.....	300,000	500,000	33,000	1.0	1.0	0.001
12 caps rinsed with 100 cc sterile water.....	870	1,100	100	5.0	5.0	.....
Water from bottling spring.....	137,000	110,000	2,000	1.0	.1	.....
Do.....	117,000	85,000	1,100	1.0	.1	.....
Water from creek 5 feet from bottling spring.....	310,000	(¹)	.....	.001	.0001	.....
Do.....	297,000	(¹)	.....	.001	.0001	.....
10 bottles collected after inspection; average results.....	2,220	2,262	98	2.1	.....	.....

¹ Liquefied.

² This determination was made at the time the sample was received at the laboratory.

TABLE III.—Results of the bacteriological examination of water collected from spring No. 3.

Description of sample.	Colonies of organisms per cc developing after—			Smallest quantity in which were found—		
	2 days' incubation on nutrient agar at 37° C.	4 days' incubation on nutrient gelatin at 20° C.		<i>B. coli.</i>		Molds.
		Total count.	Liquefiers.	At time of collection.	2 days after collection.	
"Clean" bottle rinsed with 100 cc sterile water.....	2,700	3,700	110	cc. 1.0	cc. 1.0	cc.
"Dirty" bottle rinsed with 100 cc sterile water.....	37,000	40,000	3,300	.01	.01	.....
Water used for washing and rinsing bottles.....	1,000	2,100	30	.1	.1	.....
Do.....	1,700	1,500	40	.1	.1	.....
Water from bottling spring.....	14	4	0	(¹)	(¹)	.....
Do.....	8	3	0	(¹)	(¹)	.....
Water from receiving tank from spring.	330	290	190	10.0	10.0	.....
Do.....	110	170	60	10.0	10.0	.....
Water from feeding tank for bottling.	170	3,100	0	1.0	5.0	.....
6 bottles collected before inspection; average results.....	10,100	33,500	313	2.01	.....	.....

¹ No *B. coli* were present in 10 cc quantities.² This determination was made at the time the sample was received at the laboratory.

TABLE IV.—Summary of the bacteriological examinations of water from American springs.

Spring No.	Number of sam- ples.	Num- ber of bottles.	Number of colonies of bacteria developing on nutrient agar or gelatin.—				Number of bottles showing <i>B. coli</i> in—						Molds.		
			At low temperature (20° or 25° C.).		At 37° C.										
			Highest.	Lowest.	Average.	Highest.	Lowest.	Aver- age.	10 cc.	5 cc.	1 cc.	0.1 cc.		0.01 cc.	0.001 cc.
1.....	3	21	25,000	210	5,784	1,120	6	250	0	0	0	0	0	0	Molds in 4 bottles.
2.....	2	8	11,200	0	2,080	1,900	0	556	5	2	2	2	2	0	
3.....	4	36	8,600	300	2,410	6,600	41	1,200	30	23	19	7	0	0	Molds in 2 bottles; Trichoderma, Penicil- lium, Cladosporium.
4.....	1	6	5	0	2	2	0	1	0	0	0	0	0	0	
5.....	1	12	10,200	29	1,782	11,100	29	1,700	0	0	0	0	0	0	
6.....	1	6	4,500	400	1,483	1,000	160	643	4	3	2	0	0	0	
7.....	3	25	39,000	600	5,400	4,600	190	720	25	25	23	16	5	2	
8.....	2	6	6	3	5	3	2	2	0	0	0	0	0	0	
9.....	1	6	15,000	1,000	7,000	16,000	1,000	8,000	0	0	0	0	0	0	
10.....	1	10	4,000	30	638	30	0	6	5	4	4	1	0	0	
11.....	1	9	5,700	700	2,300	1,700	40	440	3	3	3	0	0	0	
12.....	2	12	12,000	420	2,775	3,200	70	704	6	6	6	3	2	0	
13.....	3	15	11,500	700	4,250	8,000	700	3,837	10	10	10	8	3	0	
14.....	4	18	2,100	29	755	1,400	2	605	2	1	1	1	0	0	
15.....	6	20	1,400	1	266	27,000	30	1,994	13	12	10	6	4	0	Molds in 4 bottles.
16.....	4	33	1,480,000	270	132,050	360,000	610	34,982	15	12	9	8	5	0	
17.....	3	4	22,000	110	5,805	700	200	485	1	1	1	1	0	0	
18.....	1	6	120	20	55	900	90	381	1	0	0	0	0	0	
19.....	2	12	7,000	0	1,668	5,000	100	1,376	0	0	0	0	0	0	
20.....	3	20	4,000	20	1,159	14,000	170	2,510	1	1	1	0	0	0	
21.....	4	21	3,100	0	821	28,600	22	4,680	5	5	5	4	3	0	
22.....	2	18	44,000	700	7,469	27,000	400	7,654	12	12	12	6	5	1	
23.....	1	11	125,000	200	15,165	94,000	20	8,973	0	0	0	0	0	0	
24.....	1	1	8,000	.....	8,000	.....	20	2,000	0	0	0	0	0	0	
25.....	2	12	1,340	81	453	24	0	8	0	0	0	0	0	0	
26.....	2	24	500,000	200	12,430	70,000	1	14,384	0	0	0	0	0	0	
27.....	3	18	10,100	440	2,875	5,000	38	666	6	4	2	1	0	0	
28.....	4	47	208,000	400	47,408	147,000	3,300	42,053	29	27	25	17	16	13	
29.....	1	11	12,000	0	1,128	8	0	3	3	0	0	0	0	0	
30.....	1	6	1,200	70	461	120	17	49	0	0	0	0	0	0	
31.....	1	6	18,000	1,500	6,066	50,000	4,200	15,533	0	0	0	0	0	0	
32.....	3	20	24,000	1,400	11,665	5,000	140	12,675	19	14	14	9	1	0	
33.....	4	25	126,000	90	6,712	50,000	40	3,258	14	12	0	0	0	0	Molds in 4 bottles.
34.....	5	24	22,000	90	3,625	33,000	2	2,566	9	8	4	1	0	0	

TABLE IV.—Summary of the bacteriological examinations of water from American springs—Continued.

Spring No.	Number of sam- ples.	Num- ber of bot- tles.	Number of colonies of bacteria developing on nutrient agar or gelatin—					Molds.								
			At 37° C.													
			At low temperature (20° or 25° C.).		Average.	Highest.	Lowest.		A ver- age.							
			Highest.	Lowest.												
35.	4	24	8,300	320	3,025	4,500	4	935	10	8	5	1	0.1 cc.	0.01 cc.	0.001 cc.	Penicillium and Citromyces in 11 bottles.
36.	3	7	2,800	70	1,015	260	90	166	3	3	3	2	0	0	0	
37.	3	22	12,500	70	1,863	1,550	60	289	15	15	13	11	4	0	0	
38.	3	6	23,000	4,700	12,000	8,200	900	3,700	0	0	0	0	0	0	0	
39.	1	6	6,400	90	1,918	800	90*	276	0	0	0	0	0	0	0	
40.	2	6	5,200	50	1,238	3,000	70	671	4	4	4	3	2	0	0	
41.	1	6	3,100	460	1,303	4,490	11	152	6	6	6	3	0	0	0	
42.	1	12	400	4	107	1,129	61	248	0	0	0	0	0	0	0	
43.	1	5	400	80	252	200	70	127	0	0	0	0	0	0	0	
44.	2	12	16,200	2,000	9,175	9,900	1,000	4,816	0	0	0	0	0	0	0	
45.	3	24	81,000	4,000	39,140	32,000	1	12,867	12	12	12	10	2	0	0	
46.	2	18	84,000	3,000	38,916	101,000	18,000	48,333	8	7	4	2	0	0	0	
47.	2	11	3,250	60	894	2,000	1,000	1,500	11	11	11	11	0	0	0	
48.	1	1	7,000	2,000	3,616	.....	.....	8,000	1	1	1	1	0	0	0	
49.	1	6	.....	.....	.....	.....	.....	.....	4	4	4	4	0	0	0	
50.	1	1	.....	.....	.....	.....	.....	.....	1	1	1	1	0	0	0	
51.	1	6	33	3	10	7	1	3	0	0	0	0	0	0	0	
52.	1	12	7	0	3	54	2	10	0	0	0	0	0	0	0	
53.	8	69	66,000	0	8,642	16,400	30	490	48	47	36	15	5	0	0	
54.	1	2	3,400	1,500	2,500	5,000	1,700	3,350	2	2	2	2	2	1	0	
55.	2	18	170,000	3,300	50,000	135,000	700	40,000	18	17	15	14	11	10	10	
56.	4	27	58,000	130	9,401	27,000	50	2,026	15	15	14	13	6	1	1	
57.	1	11	4,800	80	828	550	55	220	7	5	5	5	0	0	0	
58.	1	12	70,400	820	13,593	42,700	60	6,479	5	3	3	3	2	1	1	
59.	1	1	.....	.....	.....	.....	.....	.....	20,000	20,000	20,000	20,000	20,000	20,000	20,000	
60.	1	2	19,000	14,000	16,500	16,000	11,000	13,500	1	1	1	1	1	1	1	
61.	1	6	1,350	650	955	.....	.....	.....	0	0	0	0	0	0	0	
62.	1	3	1,800	500	9,233	3,500	600	1,606	0	0	0	0	0	0	0	
63.	1	6	79,000	7,200	41,533	3,400	1,100	1,266	6	6	6	6	6	6	1	
64.	1	6	17	0	3	3	0	1	0	0	0	0	0	0	0	
65.	1	6	1,750	370	818	.....	.....	.....	90	976	6	6	6	6	0	
66.	1	6	65,000	6,000	17,050	2,900	90	976	6	6	6	6	6	6	0	
67.	1	12	270	0	62	16	0	1+	0	0	0	0	0	0	0	
68.	4	36	50,000	225	13,673	30,000	60	5,300	4	4	4	4	4	2	0	
69.	4	19	14,000	10	2,468	6,000	10	1,134	5	4	4	4	4	2	0	

Penicillium and Citromyces in 11 bottles.

Molds in 0.001 cc dilution in every bottle.

TABLE V.—Summary of the bacteriological examinations of samples of imported waters

Spring No.	Num-ber of bot-tles.	Num-ber of colonies of bacteria developing on nutrient agar or gelatin—	Number of bottles showing <i>B. coli</i> in—				Molds.						
			At 37° C.										
			At low temperature (20° or 25° C.).		At 37° C.								
			Highest.	Lowest.	Average.	Average.							
1	1	3	70	12	40	80	7	40	2,832	0	0	0	0
2	2	5	25,000	440	6,148	14,000	30	0	0	0	0	0	0
3	1	5	31	2	11	18	0	0	0	0	0	0	0
4	5	36	800	0	58	250	0	0	0	0	0	0	0
5	1	6	1,200	0	390	540	1	1	334	0	0	0	0
6	1	5	3,900	450	1,612	190	5	5	0	0	0	0	0
7	1	1	5,000	5,000	5,000	3,000	3,000	3,000	0	0	0	0	0
8	1	4	30	0	10	120	2	2	32	2	2	2	0
9	1	7	1	0	.....	4	3	3	3	0	0	0	0
10	2	5	210,000	3,300	130,000	840	110	424	0	0	0	0	0
11	1	4	1,100	140	567	900	400	622	4	4	2	2	0
12	2	7	1,385	2	14	16	2	9	0	0	0	0	0
13	2	6	1,010	20	308	640	6	195	0	0	0	0	0
14	1	11	22,400	1,100	6,563	11	300	0	6	0	0	0	0
15	1	6	4,300	700	2,450	800	110	455	0	0	0	0	0
16	1	1	20	0	10	500	50	225	2	1	0	0	0
17	2	6	1,600	80	670	9,000	40	2,510	0	0	0	0	0
18	1	1	1,400	40	652	120	3	70	1	0	0	0	0
19	1	4	21,000	1,500	7,400	4,000	500	0	2	0	0	0	0
20	1	5	7,000	160	2,592	29,000	470	20	1	0	0	0	0
21	1	1	3,000	3	255	400	0	82	0	0	0	0	0
22	1	4	24,000	120	9,410	1,200	40	35	0	0	0	0	0
23	1	4	8,200	72	2,745	0	16	482	6	5	5	3	0
24	6	39	11,000	40	1,405	6,000	0	960	7	7	4	2	0
25	3	7	150	0	30	3	0	44	0	0	0	0	0
26	1	1	10	0	22	1	0	25	1	1	0	0	0
27	1	6	27,000	2	6,546	7,000	1	1,761	0	0	0	0	0
28	1	8	120,000	4	44,500	8	8	2	2	2	1	0	0
29	5	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1	2											
31	1	5											
32	1	1											
33	1	1											
34	1	4											
35	2	6											

Molds in 2 bottles.

Molds in 2 bottles.

[illegible]

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 370



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LOGAN WALLER PAGE, Director

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PROFESSIONAL PAPER

July 20, 1916

THE RESULTS OF PHYSICAL TESTS OF ROAD-BUILDING ROCK.

By PRÉVOST HUBBARD, *Chemical Engineer*, and FRANK H. JACKSON, Jr., *Assistant Testing Engineer*.

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INTRODUCTION.

The purpose of this bulletin is to furnish highway engineers with the results of physical tests of road-building rock made in the laboratories of the United States Office of Public Roads and Rural Engineering to January 1, 1916. It is proposed to revise this bulletin from time to time, so that additional data secured by the office may become promptly available. Detailed descriptions of the methods of determining the physical properties of road-building rocks have been given in a recent publication by Jackson.¹ Interpretation of the results of these tests has, however, been reserved for publication with the tabulated data here given. It should be noted that Bulletins Nos. 347 and 370 therefore constitute a complete revision of Office of Public Roads Bulletin No. 44, by Albert T. Goldbeck and Frank H. Jackson, Jr., which was published in 1912. As a matter of interest it may be stated that since January 1, 1912, approximately 1,350 additional samples have been classified and tested, raising the total number from the United States and Canada to about 3,650.

¹ United States Department of Agriculture Bulletin No. 347.

AGENCIES CAUSING ROAD DETERIORATION.

Roads may deteriorate from both external and internal causes. The destructive agencies may be classified as mechanical, chemical, and physical, but in some respects it is more convenient to consider deterioration as being due to the effect of (1) traffic, (2) climatic conditions, and (3) faulty construction. The first two are external agencies and the latter is internal.

Traffic.—Traffic divides itself into two classes, (a) horse-drawn vehicles and (b) self-propelled or motor-driven vehicles. In the former the impact of horses' feet tends to disturb the position of individual fragments of rock in the wearing course and also to fracture the rock. At the same time wheels, especially steel-tired wheels, not only exert an abrasive action which grinds away the rock surfaces, but tend to crush the fragments of rock in proportion to the load per unit width of tire.

Automobile traffic exerts a severe shearing action upon the road surface which tends to loosen the individual fragments and, ultimately, to remove them from the road. Where chains or armored tires are used, considerable abrasion may also result, especially under those conditions which favor slipping or skidding.

Climatic agencies.—So far as the rock itself is concerned, climatic or weather conditions are not important destructive agencies. While it is true that rain and surface waters gradually dissolve or react with certain rock-forming minerals, the action is so slow as to be practically negligible as a source of deterioration during the life of a road. Frost may cause some deterioration in the more porous types of rock, but both rain and frost are more destructive to the road structure than to the rock of which it is built. Wind also is a negligible factor so far as the rock is concerned.

Faulty construction.—Faulty construction may result in rapid deterioration of the road proper, due to a number of causes, such as poor drainage, lack of proper consolidation, the use of the wrong size or wrong grading of broken stone, etc. Destruction or disintegration of the fragments of rock may also be hastened by these errors in construction.

FACTORS INFLUENCING THE SELECTION OF ROCK FOR ROAD BUILDING.

In accordance with the preceding discussion it is evident that from the standpoint of destructive agencies traffic conditions are the most important factors to be considered in the selection of rock for road building. Availability as well as relative cost are also important factors in so far as ultimate economy is concerned, but need not be considered in this bulletin. In addition, the type of road to be

constructed is a most important consideration, and in general the selection of rock should be based upon the character and volume of traffic as related to the type of road in which it is to be used.

The more common types of road in which stone is used are:

1. Water-bound broken-stone roads, as macadam, maintained as such.

2. Water-bound macadam roads maintained with dust palliatives.

3. Water-bound macadam roads with bituminous carpet.

4. Bituminous broken-stone roads with a seal coat of bituminous material constructed according to the penetration method.

5. Bituminous concrete roads with a seal coat of bituminous material.

6. Bituminous concrete roads without a seal coat of bituminous material.

7. Portland cement concrete roads with a coarse aggregate of broken stone.

8. Stone-block pavements.

The destructive effect of traffic, both with respect to character and volume, varies to a considerable extent for the different types of road.

PHYSICAL PROPERTIES OF ROAD-BUILDING ROCK.

The success or failure of a rock for road building depends largely upon the extent to which it will resist the destructive influences of traffic. The three most important physical properties are hardness, toughness, and binding power. Hardness is the resistance which the rock offers to the displacement of its surface particles by abrasion; toughness is the resistance which it offers to fracture under impact; and binding power is the ability which the dust from the rock possesses, or develops by contact with water, of binding the large rock fragments together. In order to approximate as closely as possible in the laboratory the destructive effects produced by the various agencies which have been mentioned, certain physical tests have been developed. Brief descriptions of these tests are as follows:

HARDNESS TEST.

Hardness is determined by subjecting a cylindrical rock core 25 mm. in diameter, drilled from the specimen to be examined, to the abrasive action of quartz sand fed upon a revolving steel disk. The end of the specimen is worn away in inverse ratio to its hardness and the amount of loss is expressed in the form of a coefficient as follows:

Coefficient of hardness = $20 - \frac{1}{3} w$, where w equals the loss in weight after 1,000 revolutions of the disk.

TOUGHNESS TEST.

Toughness is determined by subjecting a cylindrical test specimen 25 by 25 millimeters (1 by 1 inch) in size to the impact produced by the fall of a 2-kilogram (4.4-pound) hammer upon a steel plunger whose lower end is spherical and rests upon the test piece. The energy of the blow delivered is increased by increasing the height of fall of the hammer 1 centimeter (0.39 inch) after each blow. The height of blow in centimeters at failure of the specimen is called the toughness.

DEVAL ABRASION TEST.

A test devised by the French for measuring the combined action of abrasion and impact is as follows: Five kilograms (11 pounds) of freshly broken rock between 2 and 2½ inches in size is tested in a special form of cylinder so mounted on a frame that the axis of rotation of the cylinder is inclined at an angle of 30° with the axis of the cylinder itself. The fragments of rock forming the charge are thus thrown from end to end twice during each revolution, causing them to strike and rub against each other and the sides of the cylinder. After 10,000 revolutions the resulting material is screened through a $\frac{1}{16}$ -inch sieve and the weight of the material passing is used to calculate the per cent of wear. The French coefficient of wear is calculated from the per cent of wear as follows:

$$\text{French coefficient of wear} = \frac{40}{\text{Per cent wear}}.$$

CEMENTING-VALUE TEST.

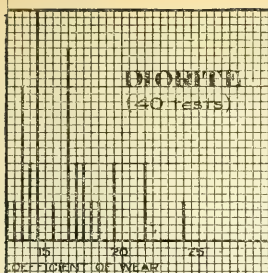
To determine the binding power, or cementing value, as it is usually called, 500 grams (1.1 pounds) of the material to be tested is crushed to pea size and ground with water in a ball mill until it has the consistency of a stiff dough. It is then molded into cylindrical briquettes 25 by 25 millimeters (1 by 1 inch) in size, which, after thorough drying, are tested to destruction in a special form of impact machine. A 1-kilogram (2.2-pound) hammer falls through a constant height of 1 centimeter (0.39 inch) upon an intervening plunger, which in turn rests upon the test piece. By means of a suitable arrangement a graphic record of the number of blows required to destroy the specimen is obtained. The number of blows producing failure is called the cementing value of the material.

SPECIFIC GRAVITY—WEIGHT PER CUBIC FOOT—WATER ABSORPTION.

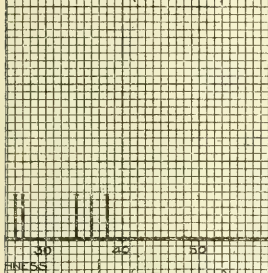
The specific gravity, weight per cubic foot, and the water absorption in pounds per cubic foot are obtained on samples of rock which are tested to determine their road-building qualities. The weight

DIORITE

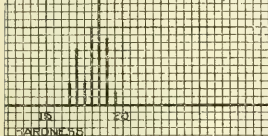
(40 tests)



(37 tests)

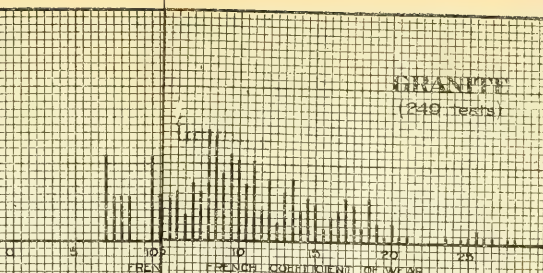


(35 tests)

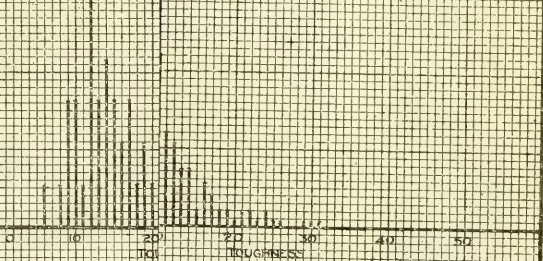


GRANITE

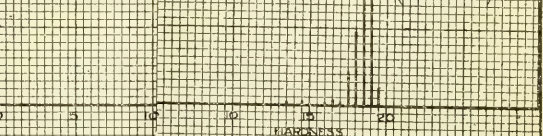
(249 tests)



(300 tests)

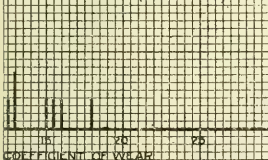


(261 tests)

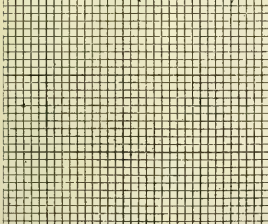


MARBLE

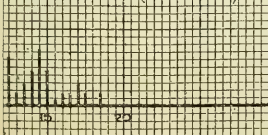
(55 tests)



(57 tests)

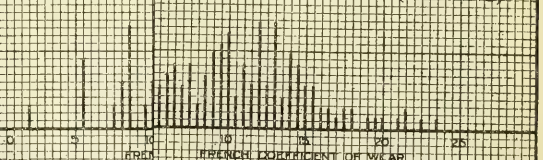


(56 tests)

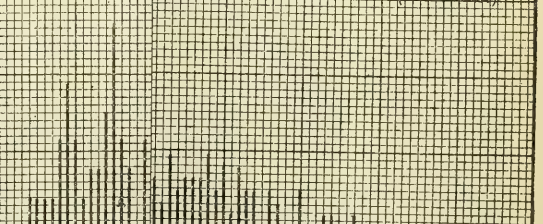


SCHIST

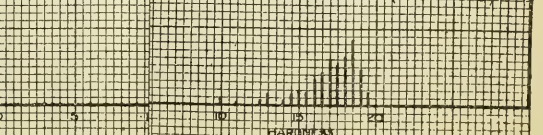
(149 tests)

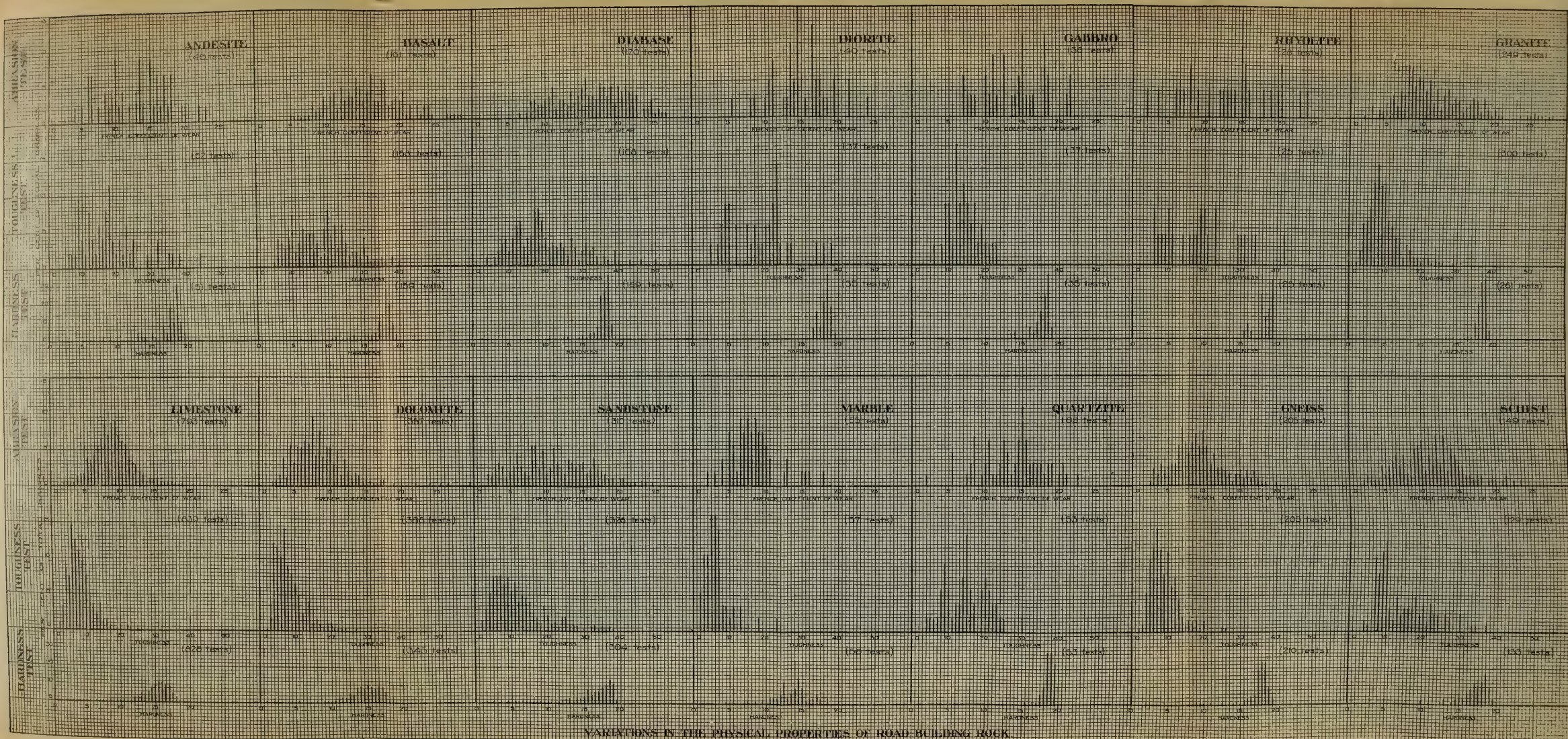


(129 tests)



(133 tests)





VARIATIONS IN THE PHYSICAL PROPERTIES OF ROAD BUILDING ROCK.

per cubic foot is calculated from the specific gravity of the material obtained on a 10-gram sample by the usual displacement method. The gain in weight of this fragment after four days' continuous immersion in water is used to calculate the water absorption in pounds per cubic foot of the solid rock.

VARIATIONS IN RESULTS OF TESTS.

Because of the fact that the various rock families, when subjected to the tests outlined above, give results which are more or less distinctive of a group or type, these results can best be discussed in many cases collectively. There are 14 families of rock which are more or less commonly used in macadam-road construction. The variations which have been found to exist in the three principal tests for each of these are shown in graphic form in the accompanying chart. The values of the tests are arranged as abscissæ, with the zero points to the left and the values numerically increasing toward the right. The ordinates or vertical lines represent the percentages of the total number of samples having values corresponding to the abscissæ on which they are plotted. The figures in parentheses in the upper right-hand corner of each block represent the total number of determinations from which these percentages were calculated.

TRAP-ROCK GROUP.

The first six rock families, *Andesite*, *Basalt*, *Diabase*, *Diorite*, *Gabbro*, and *Rhyolite*, comprise the well-known group of road-building rocks commonly known as "trap." They are all of igneous origin, but are denser and finer grained than the granites, possessing as a rule a peculiar interlocking crystalline structure which imparts to them their distinguishing characteristic—high toughness. Thus, by referring to the chart, it will be noted that the average toughness of all the traps, with the exception of gabbro, which runs somewhat lower, is about 18. This is a considerably higher average than that shown by any of the other types or groups. The same relationship holds true in the abrasion test, the average French coefficient of wear running from about 13 to 15. Comparatively slight variations in hardness are noted for any family or for the group as a whole, the average hardness for which is about 18. The binding power of the traps, as determined by test, varies through wide limits, depending largely on the degree of weathering they have undergone, as shown by Lord.¹ The specific gravity of this group averages about 2.9, giving an average weight per cubic foot of 180 pounds. Individual samples are seldom less than 2.7 nor more than 3.2 specific gravity. Water absorption may vary from a few hundredths of 1 per cent to over 7 per cent.

¹ United States Department of Agriculture Bulletin No. 348.

GRANITES.

Granite, the typical rather coarse-grained igneous rock, is characterized by low toughness and high hardness. The average value for the former, as will be seen from the chart, is about 8, while that for the latter runs as high as for the trap group, about 18.5. The abrasion test develops an average French coefficient of wear of about 11, somewhat lower than for the trap-rock group. Cementing values made on granites run low, as has been demonstrated by experience, the only exceptions being very highly weathered material which usually shows low toughness and resistance to wear. The specific gravity of the granites averages close to 2.7 and is seldom less than 2.6 or more than 2.8. The weight per cubic foot, therefore, averages 168 pounds, and may ordinarily vary from 163 to 175 pounds. Water absorption has been found to run from about 0.04 to 3 per cent.

LIMESTONES AND DOLOMITES.

The limestones and dolomites, or magnesium limestones, are undoubtedly the most widely used road-building rock. It will be seen from the chart that they run much lower in hardness, toughness, and resistance to wear than do the traps or granites. The average French coefficient of wear is about 8, toughness 7, and hardness 15. The cementing values are usually good, about 75 per cent of all samples tested running over 25. The specific gravity of the limestones and dolomites averages close to 2.7, about that of the granites, and is seldom less than 2.6 or more than 2.85. In general, the weight per cubic foot will run from 160 to 178 pounds, with an average of about 168 pounds for the limestones and 170 pounds for the dolomite. Absorption may vary from a few hundredths of 1 per cent to over 13 per cent.

SANDSTONES.

The sandstones are characterized by wide variations in the results of all tests. In fact, the highest and lowest values obtained for all samples tested have, with one exception, been upon sandstone. The average French coefficient of wear is about 12, average toughness about 10, and average hardness about 16. The cementing value of sandstones varies widely, depending upon their composition. Thus certain varieties of feldspathic sandstone somewhat resembling trap rock in appearance almost invariably show high binding value in the laboratory. Their specific gravity also varies between wide limits, but usually lies between 2.4 and 2.8, with an average of 2.62. The weight per cubic foot therefore varies from 150 to 175 pounds and averages 164 pounds. Absorption runs from a few hundredths of 1 per cent to about 2 per cent.

MARBLE AND QUARTZITE.

Marble and quartzite are the two families of nonfoliated metamorphic rocks corresponding to limestone and sandstone, respectively. While in some respects it is convenient to consider marble with the limestone and dolomite group, it will be seen from the chart that the average toughness of marble, about 5, is lower, and that the average hardness, which is less than 14, is also somewhat lower. Marbles usually show good cementing value tests with about the same range as the limestones and dolomites. For those samples tested, the specific gravity ordinarily falls between 2.7 and 2.9 and the weight per cubic foot averages 173 pounds, which is somewhat higher than the average for either limestone or dolomite. As would therefore be expected, the maximum absorption is less, being under 2.5 per cent.

Quartzites show an average toughness of 15, as compared with 10 for the sandstones. The coefficient of hardness is also higher and for the samples tested shows a much smaller range of values than for the sandstones. The quartzites invariably show a low cementing value. Their specific gravity from tests made usually lies between 2.6 and 2.8 and their average weight per cubic foot is about 167 pounds. Their water absorption runs from a few hundredths of 1 per cent to nearly 3 per cent.

GNEISS AND SCHIST.

Both gneiss and schist belong to the foliated metamorphic type of rocks. The former is in reality a metamorphosed granite and therefore shows physical properties similar to the granites. The average French coefficient of wear for the gneiss samples is about 9, being somewhat lower than for the granites, while their average hardness and toughness is about the same. Their specific gravity, weight per cubic foot, and absorption are approximately the same as for granite.

The schists show an average French coefficient of wear of about 12. Their average hardness is about 17.5 and their toughness averages 11, the latter being higher than for gneiss. It should be noted, however, that the toughness test for both gneiss and schist is made perpendicular to the plane of foliation. If taken horizontal to the plane of foliation much lower results would be obtained, as failure would then occur along these natural lines of cleavage. The specific gravity of schists usually lies between 2.65 and 2.90 and the average weight per cubic foot is about 181 pounds. Water absorption is seldom over 2 per cent for this family.

With the exception of the highly altered varieties, both gneisses and schists show a rather low cementing value.

CHERT.

Chert is a very hard material, but frequently shows a low resistance to wear, owing to its tendency to fracture along lines which have developed as shrinkage cracks in the rock structure. For this reason it is extremely difficult to test for toughness. The cementing value of pure chert is usually low, but some highly weathered deposits develop in service good cementing value, especially if a high-binding clay is associated with it. Comparatively few samples which have been submitted for examination have been found suitable for all tests. Of those examined, however, the French coefficient of wear has usually been found to lie between 2 and 8, with an average of 5; toughness between 7 and 26, with an average of 16; and the hardness coefficient between 19 and 20. Specific gravity usually lies between 2.4 and 2.65 and the average weight per cubic foot is about 160 pounds. Water absorption may run from a few tenths of 1 per cent to over 8 per cent.

SHALE AND SLATE.

Shales and slates are highly laminated rocks that tend to break into flat plates not suitable for road-building purposes. They are seldom used in road construction, except perhaps as a filling for sub-foundations. They vary greatly in nearly all of their physical properties.

RARE ROAD-BUILDING ROCKS.

A comparatively few samples of a number of families of rocks which are occasionally used in road building have been examined in the laboratories of the United States Office of Public Roads and Rural Engineering. They need not be considered in detail, but the usual ranges as well as the averages of results of the more important physical tests of these rocks are given in Table I.

TABLE I.—*The rare road-building rocks.*

Number of samples.	Name.	French coefficient of wear.		Toughness.		Hardness.	
		Ordinary range.	Average.	Ordinary range.	Average.	Ordinary range.	Average.
20	Amphibolite.....	11.3-26.7	16.7	12-40	19	16.6-19.0	17.5
10	Eclogite.....	12.7-22.7	16.1	14-28	26	18.4-19.3	18.5
12	Epidosite.....	10.0-18.7	13.0	10-23	16	17.6-19.5	18.0
11	Felsite.....	11.9-21.3	15.8	-----	16	-----	18.7
6	Peridotite.....	7.6-13.2	10.3	9-12	10	13.3-16.6	15.0
8	Serpentine.....	2.6-14.2	10.1	11-21	14	18.3-18.6	18.4
5	Trachyte.....	11.5-23.5	16.2	21-34	22	17.7-19.1	18.1
19	Syenite.....	7.0-18.7	13.1	8-22	14	17.3-19.2	18.1

SLAGS.

Many slag varieties resemble in certain outward respects the common road-building rocks. However, in general, they are more porous and glassy, and vary so greatly in physical properties that with reference to their physical characteristics from the standpoint of road construction they can not well be considered as a single class with definite limits or general average numerical values.

INTERPRETATIONS OF RESULTS OF PHYSICAL TESTS.

The results of physical tests are only of value in predetermining the suitability of a rock for a given type of road under given conditions when the behavior of other rocks, having the same general physical characteristics, is known. Much investigation is still necessary to accurately correlate laboratory tests with service results, but in this connection certain facts have been determined from experience, which may be briefly discussed under the different types of roads.

As the amount of traffic to which a road is or will be subjected is a most important consideration, and as the terms light, moderate, and heavy are commonly used in describing the amount of traffic, such terms should be defined. For the purpose of comparison it has been assumed that traffic of less than 100 vehicles per day is light, between 100 and 250 moderate, and over 250 heavy.

WATER-BOUND MACADAM ROADS.

The ideal rock for the construction of a water-bound macadam road resists the wear of traffic to which it is subjected to just that extent which will supply a sufficient amount of cementitious rock dust to bind or hold the larger fragments in place. It is generally admitted that the ordinary macadam road is not well suited to any considerable amount of automobile traffic, because such traffic rapidly removes the binder without producing fresh material to take its place.

Cementing value is a necessary quality for rocks used in macadam road construction. As determined by test, cementing values below 25 are called low; from 26 to 75, average, and above 75, high. In general, the cementing value should run above 25. For rocks which show a low French coefficient of wear, however, a relatively high cementing value is more necessary than for those which have a high French coefficient. Interpretation of results of the cementing value test is subject to a number of influencing considerations. For instance, it has been found that certain feldspathic varieties of sandstone give excellent results in this test, while experience has shown that they do not bind well when used in the wearing course of macadam roads. In the case also of certain varieties of the trap

group low results are frequently shown by laboratory tests for rocks which bind quite satisfactorily upon the road, provided traffic is sufficiently heavy to supply the requisite amount of fine material. Certain granites, gneisses, and schists which are not suitable for use as binding material give good results in this test. In such cases it is usually found that the highly altered nature of the material reduces its toughness and resistance to wear to such an extent as to condemn it for use.

Experience has shown that in general the following table of limiting values for the French coefficient of wear, toughness, and hardness may be used in determining the suitability of a rock for the construction of the wearing course of a macadam road:

TABLE II.—*Limiting values of physical tests of rock for water-bound macadam road construction.*

Character of traffic.	Limits of tests.		
	French coefficient of wear.	Toughness.	Hardness.
Light.....	5-8=(5-8 per cent wear).....	5-9	10-17
Moderate.....	8-15=(2.7-5 per cent wear).....	10-18	Over 14
Heavy.....	Over 15=(less than 2.7 per cent wear).....	Over 18	Over 17

With relation to the limitations for hardness it may be noted that as a result of comparing hardness and toughness tests of some 3,000 samples, the authors¹ have shown that when any given value for toughness falls within certain limits which define the suitability of the material for macadam road construction under given traffic conditions, the corresponding value for hardness will fall within similar limits for hardness. In this connection it will be seen, in Table II, that a maximum limit for hardness is only given in the case of light traffic. It has been found that the great majority of samples having a French coefficient of wear of from 5 to 8 and a hardness of over 17 are granites, quartzites, and hard sandstones, which are unsuited for use in the wearing course of water-bound macadam roads due to their lack of binding power.

BITUMINOUS ROADS.

For broken-stone roads which are maintained with dust palliatives, the same limits for French coefficient of wear and toughness should hold as for ordinary macadam roads.

In bituminous work observations indicate that in some cases it is advantageous to use a rock of relatively high absorption rather than one with low absorptive qualities, owing to a better adhesion of the bituminous material by a partial surface impregnation of the rock.

¹ Relation Between the Properties of Hardness and Toughness of Road-Building Rock, Journal of Agricultural Research, Vol. V, No. 19, D-3.

While the binding or cementing value of a rock is a most important consideration from the standpoint of ordinary macadam construction, the same is not true of broken-stone roads which are carpeted or constructed with an adhesive bituminous material. The French coefficient of wear is also of relatively less importance, owing to the fact that the fine mineral particles produced by the abrasion of traffic combine, or should combine, with the bituminous material to form a mastic which is held in place and protects the underlying rock from abrasion so long as by proper maintenance it is kept intact. The toughness of the rock is of more importance, as the shock of impact is to a considerable extent transmitted through the seal coat and may cause the underlying fragments to shatter. It would, therefore, seem that the minimum toughness of a rock for use in the construction of a bituminous broken-stone road or a broken-stone road with a bituminous-mat surface should, for light traffic, be no less than for ordinary macadam subjected to the same class of traffic. For moderate and heavy traffic, however, the same minimum toughness should prove sufficient, owing to the cushioning effect of the bituminous matrix. No maximum limit of toughness need be considered for any traffic.

In the case of bituminous concrete roads, where the broken stone and bituminous material are mixed prior to laying and consolidation, it generally appears advisable to set a minimum toughness of 6 or 7 for light-traffic roads, instead of 5, in order to insure that the fragments of rock which have been coated with bitumen shall not be fractured under the roller during consolidation; and 12 or 13 for moderate and heavy traffic, instead of 10 and 19, as in the case of water-bound macadam roads.

Bearing in mind the fact that availability, cost, and various local conditions may often modify the selection of proper limits, Table III may be used as a general guide for minimum limits of French coefficient of wear and toughness in connection with bituminous broken-stone roads.

TABLE III.—*Minimum limits of physical tests of rock for bituminous-road construction.*

Type of road.	Light to moderate traffic.		Moderate to heavy traffic.	
	French coefficient of wear.	Toughness.	French coefficient of wear.	Toughness.
Broken stone with bituminous carpet.	5=(not over 8 per cent wear).	5	7=(not over 5.7 per cent wear).	10
Bituminous broken stone with seal coat.				
Bituminous concrete with or without seal coat.	7=(not over 5.7 per cent wear).	7	10=(not over 4 per cent wear).	13

PORTLAND CEMENT CONCRETE AND STONE BLOCK.

The most desirable limitations for broken stone to be used as coarse aggregate in Portland cement concrete wearing surfaces has not as yet been ascertained. In general, however, it would seem that the low limit for hardness should be no less than the hardness of the mortar which binds the rock fragments together. At the present time a minimum hardness of 12 for moderate and 16 for heavy traffic would appear reasonable. In consideration of the type of traffic to which concrete roads are subjected, a minimum toughness of 8 is suggested.

Stone blocks are usually manufactured from granite or sandstone, although other rocks may also be used. Specifications for granite block adopted in 1914 by the American Society of Municipal Improvements¹ call for a toughness of not less than 9 and a crushing strength of not less than 20,000 pounds per square inch. It would appear wise to also require that the hardness be not less than 16.

APPENDIX.

The results of all of the physical tests made on rock samples in the laboratory of the Office of Public Roads and Rural Engineering from the date of its installation in 1902 up to January 1, 1916, are included in Table V, together with the results obtained by Logan Waller Page for the Massachusetts State Highway Commission previous to 1902.

The rocks are classified according to their location, so that this table shows the availability and character of the materials, as far as they have been tested, throughout the United States.

Table IV shows the number of samples of material tested in the different States.

TABLE IV.—*Geographical distribution of samples tested.*

State.	Number of samples tested.	State.	Number of samples tested.	State.	Number of samples tested.
Alabama.....	29	Massachusetts.....	179	South Dakota.....	11
Arizona.....	3	Michigan.....	84	Tennessee.....	61
Arkansas.....	14	Minnesota.....	16	Texas.....	62
California.....	101	Mississippi.....	11	Utah.....	13
Colorado.....	21	Missouri.....	33	Vermont.....	32
Connecticut.....	43	Montana.....	4	Virginia.....	404
Delaware.....	30	Nebraska.....	11	Washington.....	212
Florida.....	9	New Hampshire.....	22	West Virginia.....	139
Georgia.....	157	New Jersey.....	72	Wisconsin.....	139
Idaho.....	9	New York.....	136	Wyoming.....	3
Illinois.....	122	North Carolina.....	137		
Indiana.....	151	Ohio.....	138		3,605
Iowa.....	23	Oklahoma.....	50	Canada.....	49
Kansas.....	11	Oregon.....	14	Porto Rico.....	12
Kentucky.....	41	Pennsylvania.....	599	Cuba.....	4
Louisiana.....	7	Rhode Island.....	38		
Maine.....	72	South Carolina.....	26	Total.....	3,670
Maryland.....	116				

¹ Proceedings of the 1914 Convention of the American Society of Municipal Improvements, p. 511.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916.

ALABAMA.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
1108	Francis.	Calhoun.	Chert.	153	1.74	9.0	4.4	19.3	11	22
1478	Anniston.	do.	Limestone.	168	.27	3.9	10.3	15.2	9	62
4382	do.	do.	Quartzite.	165	.20	3.4	11.7	19.7	21	2
2450	Cullman.	do.	Sandstone.	153	.94	4.8	15.1	19.7	10	37
7587	do.	do.	do.	156	.97	9.2	4.4	18.5	6	4
7588	do.	do.	do.	159	.11	6.6	6.1	17.8	6	5
7786	do.	do.	Feldspathic sandstone.	156	2.00	8.6	4.7	15.6	7	33
2451	do.	do.	Limestone.	168	.55	3.4	11.6	15.1	8	37
2856	do.	do.	do.	165	.62	6.8	5.8	12.9	6	36
5054	Selma.	Dallas.	do.	165	1.56	7.8	5.1	15.0	7	25
7031	Gadsden.	do.	do.	161	.31	4.7	8.5	15.4	4	15
805	Berry.	Etowah.	do.	188	.34	3.1	13.0	(1)	(1)	(1)
426	Furnessdale.	Fayette.	do.	182	2.56	17.4	2.3	(1)	(1)	(1)
391	Birmingham.	Hall.	Chert.	162	1.28	10.2	3.9	(1)	(1)	(1)
392	do.	do.	do.	159	2.24	8.2	4.9	(1)	(1)	(1)
393	do.	do.	do.	153	3.40	9.5	4.2	(1)	(1)	(1)
966	Leeds.	do.	do.	162	.64	15.8	5.2	(1)	(1)	(1)
395	Birmingham.	do.	Blast-furnace slag.	168	.54	7.6	5.2	(1)	(1)	(1)
2493	do.	do.	Slag.	169	1.32	9.9	4.0	14.2	6	262
8879	do.	do.	Blast-furnace slag.	166	2.73	10.1	4.0	17.0	6	81
8880	do.	do.	do.	175	.68	(1)	(1)	17.0	6	49
442	do.	do.	Dolomite.	168	1.24	5.7	7.1	(1)	(1)	(1)
1517	do.	do.	Limestone.	159	2.91	6.5	6.1	15.4	10	129
6856	New Decatur.	Morgan.	Crystalline limestone.	172	.96	3.9	10.2	15.4	7	106
7937	Leeds.	St. Clair.	Weathered chert.	143	.54	13.8	2.9	(1)	(1)	13
2854	Dorville Switch.	Truscaloosa.	Limestone.	168	.10	4.6	8.4	17.7	8	57
1575	Furnan.	Wilcox.	do.	162	2.76	4.8	8.4	10.3	7	55
1580	Snowhill.	do.	do.	162	2.57	17.1	8.9	17.1	8	68
1643	Pineapple.	do.	do.	156	4.89	5.3	7.5	11.0	6	65

ARIZONA.

7837	(2) Phoenix.	Cochise.	Limestone.	168	0.41	5.3	7.6	18.1	6	43
4408	Maricopa.	do.	Schist.	187	.31	3.1	12.9	17.5	14	54
4103	U. S. Government.	do.	Altered andesite.	162	1.95	2.4	16.5	17.6	23	500

¹ Test not made.² Exact locality not known.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916—Contd.*

ARKANSAS.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
4754	Herber Springs.....	Cleburne	Slate.....	Pounds. 168	Pounds. 0.72	5.6	7.1	9.3	16	21
5680	(1).....	do.	Argillaceous sandstone.....	168	1.35	3.6	11.2	11.4	19	117
5403	Van Buren.....	Crawford	Feldspathic sandstone.....	162	.87	4.5	8.9	15.2	10	34
8921	Alma.....	do.	Sandstone.....	165	.79	2.3	17.0	18.3	10	8
2846	Conway.....	Faulkner	Ferruginous sandstone.....	159	1.63	4.9	8.1	17.1	9	23
438	Hot Springs.....	Garland	Chert.....	162	.46	11.1	3.6	(2)	(2)	(2)
7629	Hope.....	Hempstead	Ferruginous sandstone.....	184	1.54	6.9	5.8	18.2	12	32
2298	Paris.....	Logan	Feldspathic sandstone.....	159	1.27	2.4	16.9	18.9	10	77
1353	Texasiana.....	Miller	Ferruginous sandstone.....	178	2.28	4.6	8.6	18.2	16	26
2158	Little Rock.....	Pulaski	Feldspathic sandstone.....	175	.25	2.3	17.4	18.9	37	41
742	Fort Smith.....	Sebastian	Sandstone.....	156	1.39	4.0	10.1	(2)	(2)	70
743	do.....	do.	do.....	162	1.28	3.7	10.7	(2)	(2)	50
6331	Bald Knob.....	White	do.....	159	2.05	2.2	18.2	17.9	18	41
6954	(1).....	Yell	Quartzite.....	165	.54	2.7	14.8	19.0	22	8

CALIFORNIA.

1227	Oakland.....	Alameda	Rhyolite (altered).....	165	0.36	1.7	23.0	18.7	33	37
5150	do.....	do.	Altered rhyolite.....	168	.50	2.7	14.8	17.9	14	25
4372	do.....	do.	Feldspathic sandstone.....	168	.48	4.7	8.5	16.5	5	177
4373	do.....	do.	do.....	168	.51	3.6	11.2	18.6	21	39
4374	do.....	do.	do.....	168	.44	3.0	13.4	18.8	24	13
4377	do.....	do.	do.....	168	.41	3.5	11.4	17.8	12	68
5151	do.....	do.	do.....	168	.48	2.2	18.0	18.7	14	94
4376	do.....	do.	Altered basalt.....	178	1.43	5.3	7.5	16.8	15	130
4375	do.....	do.	Quartz breccia.....	162	1.80	10.5	3.8	19.4	9	18
8892	Newark.....	do.	Chalcedonic quartz.....	165	.35	8.5	4.7	(2)	(2)	8
9369	Dumbarton.....	do.	Ferruginous chert.....	184	.14	15.9	3.5	(2)	(2)	33
8891	Newark.....	do.	Serpentine.....	156	4.04	11.0	3.6	12.3	6	86
9370	Dumbarton.....	do.	do.....	147	2.73	16.4	2.4	14.0	(2)	49
9371	do.....	do.	Chert conglomerate.....	165	.05	7.1	5.6	(2)	(2)	5
2031	Milton (5 miles east of).....	Calaveras	Rhyolite.....	168	.19	2.1	19.0	19.5	20	17
2032	Milton (3 miles east of).....	do.	Altered basalt.....	181	.58	1.5	27.4	19.2	19	42
2636	Milton.....	do.	Altered andesite.....	178	.11	1.5	26.0	18.8	44	32
2350	Valley Springs (near).....	do.	Quartzite.....	178	.41	3.4	11.8	19.5	15	3
2351	do.....	do.	Hornblende chlorite schist.....	178	.84	2.8	14.4	18.9	17	29

5147	San Pablo.....	Contra Costa.....	Feldspathic sandstone.....	168	.55	2.6	15.2	18.2	16
5148	Albany.....	do.....	do.....	168	1.04	5.0	7.9	17.0	11
2525	Red Hill.....	Fresno.....	Epidosite.....	187	.22	2.1	18.7	17.6	11
7605	Bakersfield.....	Kern.....	Diorite.....	184	.08	3.7	10.8	19.3	36
578	Los Angeles.....	do.....	Granite.....	162	.91	14.8	(2)	(2)	(2)
2436	Glendale.....	do.....	do.....	162	.57	(4)	(2)	(2)	4
2438	Glendale.....	do.....	Altered granite.....	165	.99	4.8	18.1	18.5	20
3261	(1).....	do.....	Hornblende granite.....	165	.42	2.5	15.9	19.0	22
2289	Spadra.....	do.....	Rhyolite.....	167	1.32	5.6	7.2	14.0	10
2353	(1).....	do.....	do.....	168	.40	2.6	15.2	16.7	21
2946	Spadra (near).....	do.....	Weathered trachytic rhyolite.....	140	5.29	4.4	9.0	16.2	17
2947	do.....	do.....	Trachytic rhyolite.....	153	1.49	5.1	7.9	18.7	19
3165	(1).....	do.....	Altered rhyolite.....	134	7.15	6.8	5.9	16.5	9
2290	Spadra.....	do.....	Andesite.....	178	.13	2.3	17.2	18.3	12
2294	Hollywood.....	do.....	do.....	172	.59	(2)	(2)	18.7	17
2334	(1).....	do.....	Augite andesite.....	165	2.43	3.4	11.9	16.6	18
2439	do.....	do.....	Andesite.....	172	.83	2.2	17.9	17.7	29
2594	San Pedro (near).....	do.....	Altered andesite.....	156	.21	4.8	8.4	(2)	(2)
2595	do.....	do.....	do.....	137	6.59	8.1	4.9	12.9	9
2983	Los Angeles.....	do.....	do.....	156	1.05	4.0	10.1	17.3	16
3262	(1).....	do.....	do.....	159	1.67	2.7	15.0	18.2	15
3263	(1).....	do.....	do.....	147	4.71	8.4	(2)	18.2	10
3264	(1).....	do.....	do.....	159	2.17	4.8	(2)	17.5	14
3346	Los Angeles.....	do.....	Hornblende andesite.....	162	1.07	3.7	10.8	16.9	17
2335	Hollywood.....	do.....	Diorite.....	172	.40	4.8	8.3	18.4	9
2293	do.....	do.....	Limestone.....	162	1.44	5.8	6.9	14.2	7
2355	Los Angeles.....	do.....	Tuffaceous limestone.....	162	4.65	3.7	10.8	17.2	10
2552	(1).....	do.....	Tremolite schist.....	181	.33	3.0	13.2	(2)	(2)
2596	do.....	do.....	Quartzite schist.....	165	.19	4.9	8.2	19.2	15
2554	San Pedro.....	do.....	Quartz syenite.....	165	.40	2.3	17.2	18.3	21
2555	(1).....	do.....	Syenite gneiss.....	168	.52	2.4	16.7	18.2	12
2556	(1).....	do.....	Biotite gneiss.....	165	1.11	(2)	(2)	18.7	11
2437	Glendale.....	do.....	do.....	172	.17	3.2	12.6	18.2	9
3166	Los Angeles.....	do.....	do.....	172	.34	3.7	10.7	18.3	10
2593	Hollywood (near).....	do.....	Granite breccia.....	162	1.99	24.6	1.6	(2)	(2)
2967	Lancaster (near).....	do.....	Altered trachyte.....	178	1.53	1.7	23.5	17.8	34
3271	(1).....	do.....	Basalt.....	168	1.69	4.0	10.0	18.6	18
2957	do.....	do.....	Feldspar basalt.....	175	.75	2.8	14.4	18.3	35
2957	Jasper Station.....	Mariposa.....	Weathered feldspathic quartzite.....	175	.20	2.0	20.4	18.7	24
2958	do.....	do.....	do.....	172	.25	2.4	16.9	18.7	16
2577	Riverside.....	do.....	Diorite.....	167	.1	1.7	23.8	18.7	8
3544	(1).....	do.....	do.....	175	.18	7.2	5.5	18.1	34
2075	Corona.....	do.....	Rhyolite.....	165	.62	2.2	18.0	17.9	5
8643	Corona (near).....	do.....	Altered rhyolite.....	168	.29	1.8	21.7	18.7	31
2076	(1).....	do.....	Andesite.....	172	1.10	3.5	11.3	17.7	20
3135	(1).....	do.....	Hornblende granite.....	162	.87	2.5	16.1	17.7	19
3545	(1).....	do.....	Dolomitic marble.....	165	.26	6.3	16.1	18.8	10
3546	(1).....	do.....	Pyroxene quartzite.....	196	.31	3.7	6.4	14.2	5
2120	Folsom.....	do.....	Altered andesite.....	175	.29	1.4	10.8	18.4	8
8300	Fair Oaks.....	do.....	Altered basalt.....	187	.17	1.7	28.6	19.3	36
								19.5	19

* Test not made.

1 Exact locality not known.

COLORADO.

3113	Boulder	Sandstone	2.11	5.3	7.6	16.5	7	16
3114	do.	Augite andesite	.52	3.0	13.3	18.3	18	135
3116	(4)	Altered andesite	2.73	2.6	13.5	18.3	20	73
3294	Crags	Altered granite	.24	2.4	16.7	18.8	13	13
2196	Silver Cliff	Rhyolite breccia	5.53	5.3	5.1	(1)	(1)	500+
2934	do.	do.	6.11	7.8	7.1	15.5	(1)	7
4994	Denver	Slag (smelter)	.25	4.3	9.3	(1)	(1)	500+
2458	Colorado Springs (near)	Trachyte	4.21	3.2	12.7	19.1	(1)	82
1372	Portland	Biotite granite	.42	8.2	4.9	(1)	(1)	47
1374	do.	Limestone	2.60	4.5	8.8	(1)	(1)	71
396	Lake City	Rhyolite breccia	.16	162	7.0	(1)	(1)	327
397	Sherman	Porphyritic granite	.44	8.7	4.6	(1)	(1)	14
398	Lake Shore post office	Rhyolite tuff	.15	8.1	5.0	(1)	(1)	327
406	do.	do.	2.90	10.3	3.8	(1)	(1)	1
399	Capitol City (near)	Brecciated felsite	3.13	3.4	11.9	(1)	(1)	1
407	Lake City (near)	Andesite	2.83	3.5	11.5	(1)	(1)	1
408	do.	Augite andesite	2.00	6.4	6.3	(1)	(1)	1
409	do.	Diorite	1.03	3.2	12.5	(1)	(1)	1
3293	Golden	Basalt	1.43	2.2	17.9	15.9	15	222
4724	Fort Collins	Limestone	3.24	6.5	6.1	(1)	(1)	32
1002	La Junta	do.	6.04	7.3	5.5	3.0	7	95

CONNECTICUT.

2798	Danbury.	Fairfield.	Marble.	0.39	5.7	7.0	15.2	6	41
3177	Bridgeport.	do.	Weldspathic quartzite.	1.65	2.2	18.2	18.5	12	15
3178	do.	do.	Granite gneiss.	.37	.38	16.8	18.5	10	35
6111	do.	do.	do.	.65	2.5	16.8	18.8	19	15
6112	do.	do.	Biotite gneiss.	1.62	3.0	13.3	18.0	11	16
3223	do.	do.	Diabase.	.17	.17	12.0	18.0	30	37
3477	Danbury.	do.	do.	.184	1.1	36.4	18.3	(1)	82
233	Rockyhill.	Hartford.	do.	(1)	2.4	17.0	(1)	(1)	(1)
2250	do.	do.	Altered diabase.	.187	1.7	23.8	18.2	24	500+
2381	Canton.	do.	Gabbroitic diabase.	1.06	(1)	18.4	18.0	13	50
3320	Rockyhill.	do.	Altered diabase.	1.35	1.8	22.7	16.8	227	192
5977	Suffield.	do.	do.	.187	1.9	20.8	18.3	33	85
7309	Hartford.	do.	do.	1.89	2.1	18.9	17.2	12	200+
4013	Plainville.	do.	Basalt.	.30	2.1	19.4	18.1	21	170
2873	New Milford.	Litchfield.	Hornblende schist.	.30	3.5	11.4	18.4	6	24
6995	Torrington.	do.	do.	1.13	3.0	13.3	16.5	8	9
5815	do.	do.	Granite gneiss.	.35	(1)	13.3	18.3	11	32
6905	Sharon.	do.	Siliceous dolomite.	.56	5.5	7.3	11.3	7	49
6750	Torrington.	do.	Amphibolite.	.16	2.3	17.4	16.9	10	18
2241	Middlefield.	Middlesex.	Diabase.	1.08	1.7	23.3	16.5	8	500+

² Exact locality not known.

1 Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

CONNECTICUT—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
11	Meriden.....	New Haven.	Augite diabase.....	Pounds. 178	Pounds. (1)	3.2	12.5	(1)	(1)	(1)
71	do.....	do.	Diabase.....	(1)	(1)	2.6	15.5	(1)	(1)	(1)
215	Brantford.....	do.	do.....	(1)	(1)	2.2	18.8	(1)	(1)	(1)
349	do.....	do.	do.....	175	.77	3.5	11.5	(1)	(1)	(1)
467	Meriden.....	do.	do.....	181	.65	2.4	16.9	(1)	(1)	287
1204	Brantford.....	do.	Altered diabase.....	172	1.03	2.4	16.5	17.6	15	500+
1324	Ansonia.....	do.	Diabase.....	190	.16	1.8	22.3	17.9	32	154
2249	Meriden.....	do.	Altered diabase.....	181	.43	1.8	22.2	17.3	17	500+
5002	Brantford.....	do.	do.....	175	.31	3.4	11.8	16.6	8	376
5758	(2).....	do.	do.....	184	2.17	2.0	20.4	18.6	23	40
8178	(2).....	do.	Diabase.....	184	1.24	2.1	19.0	17.5	19	114
354	Ansonia.....	do.	Basalt.....	187	.59	2.1	19.2	(1)	(1)	(1)
1323	do.....	do.	Biotite gneiss.....	168	.40	3.1	12.9	17.6	20	48
2795	Levyard.....	New London.	Hornblende schist.....	184	.19	3.4	11.8	18.0	18	28
1042	Rockville.....	Tolland.	Diabase.....	187	.23	2.0	19.6	(1)	(1)	101
1061	do.....	do.	do.....	187	.18	1.9	21.1	18.7	43	58
940	do.....	do.	Gneiss.....	168	.25	2.2	18.6	17.7	10	33
953	do.....	do.	Altered biotite gneiss.....	162	.68	4.7	8.5	16.6	55	55
1104	do.....	do.	Gneiss.....	190	.47	3.4	11.7	19.0	7	38
8177	do.....	do.	Hornblende schist.....	162	.67	5.2	7.7	19.0	46	46
206	Plainfield.....	Windham.	Diabase.....	(1)	(1)	1.8	22.2	(1)	(1)	(1)
1615	Williamantic (near).....	do.	Granite.....	162	1.03	11.2	3.6	15.8	30	30
1616	do.....	do.	Biotite granite.....	165	1.12	(1)	(1)	13.6	6	29

DELAWARE.

858	Greenbank.....	New Castle.	Quartzite.....	187	.08	2.7	15.1	18.4	30	31
862	do.....	do.	Quartzite (micaceous).....	168	.10	2.6	15.2	(1)	(1)	20
864	Wilmington.....	do.	Pyroxene quartzite.....	190	.12	2.2	18.3	(1)	(1)	13
1364	do.....	do.	do.....	181	.10	2.1	18.7	18.5	24	7
5711	(2).....	do.	Feldspathic quartzite.....	168	.12	2.5	16.8	18.7	21	54
863	Wooddale.....	do.	Hornblende schist.....	196	.17	3.0	13.6	16.5	18	15
2012	Mill Creek Hundred.....	do.	Biotite schist.....	168	.83	6.6	6.1	(1)	(1)	75
2029	Wooddale.....	do.	do.....	175	.39	3.3	12.2	16.8	10	33
2574	do.....	do.	Hornblende schist.....	196	.23	2.8	14.3	17.4	19	20
3490	Ashland.....	do.	do.....	187	.19	4.3	9.3	17.2	9	26
3535	Marshallton.....	do.	do.....	190	.10	5.2	7.7	17.8	11	5

4033	Wooddale.	do.	Biotite schist.	175	19	4.5	8.8	17.8	10	26
4615	(2)	do.	do.	175	.43	5.4	7.4	17.2	11	21
5875	Newark.	do.	Hornblende schist	187	.29	2.6	15.4	17.7	(1)	40
5875	Wooddale.	do.	Granite.	165	.15	3.4	11.9	(1)	(1)	22
2315	do.	do.	Biotite granite.	173	.37	3.9	10.3	17.7	6	34
4032	do.	do.	do.	168	.37	5.1	7.9	18.3	8	17
1363	Wilmington.	do.	Amphibolite.	172	.13	1.0	41.7	18.6	18	14
1365	do.	do.	Gabbro.	187	.16	1.6	25.3	18.2	17	19
3898	(3)	do.	Hypersthene gabbro.	187	.17	3.7	10.8	18.0	9	18
2347	(3)	do.	Limestone.	125	9.01	(1)	(1)	16.2	4	(1)
2348	(2)	do.	Serpentine.	125	8.86	(1)	(1)	17.6	6	(1)
3452	(2)	do.	do.	147	15.1	15.1	2.6	0.0	3	500+
3533	Hockessin.	do.	Biotite gneiss.	172	.54	12.8	3.1	17.3	7	46
3534	Marshallton.	do.	Hornblende gneiss.	190	.02	5.6	7.2	18.0	12	21
4921	(2)	do.	Biotite gneiss.	175	.27	4.4	9.2	17.0	7	55
5713	do.	do.	do.	172	.19	4.8	8.3	18.0	8	18
8736	Mill Creek Hundred.	do.	do.	175	.24	4.5	8.8	18.2	7	19
8919	Newark (near).	do.	do.	172	.57	5.0	8.0	15.9	5	21
5712	(2)	do.	Dolomitic marble.	178	.35	4.2	9.6	14.3	6	31

FLORIDA.

1129	Gainesville.	Alachua.	Chert.	(1)	(1)	13.9	2.9	(1)	(1)	64
3018	Raleigh.	do.	do.	153	1.66	7.1	5.6	(1)	(1)	6
1169	Floral City.	Citrus.	Siliceous limestone.	155	6.93	17.6	2.3	(1)	(1)	230
6858	(2)	do.	Limestone.	(1)	(1)	(1)	(1)	(1)	(1)	38
702	Tampa.	Hillsborough.	Dolomite.	162	4.80	18.6	2.2	(1)	(1)	135
6963	do.	do.	Limestone.	156	.21	9.4	4.3	5.6	3	5
5974	Fort Myers.	Lee.	Shell limestone.	153	3.17	13.1	3.0	12.3	6	65
8387	Ocala.	Marion.	Weathered chert.	143	.30	10.9	3.7	18.8	13	10
7218	Live Oak.	Suwannee.	Limestone.	162	1.06	(1)	(1)	12.1	3	37

GEORGIA.

417	(2)	Bartow.	Dolomite.	181	0.76	8.2	4.9	(1)	(1)	(1)
8692	Cartersville.	do.	do.	178	.18	(1)	(1)	17.5	14	26
9577	Union City.	Campbell.	Granite.	165	.28	3.0	13.3	18.5	6	16
424	Chickamauga Park.	Caroosa.	Decomposed limestone.	168	.13	4.9	8.3	(1)	(1)	(1)
8721	Graysville.	do.	Siliceous limestone.	168	.32	5.5	7.3	14.7	7	30
8708	Summerville.	Chattooga.	Limestone.	168	.27	4.5	8.9	15.7	9	41
933-A	Holton (2 miles north of).	Bibb.	Biotite gneiss.	(1)	(1)	(1)	(1)	16.2	4	(1)
933-B	do.	do.	do.	165	2.00	5.7	7.0	19.3	4	14
583	Canton.	Cherokee.	Eclogite.	228	.14	2.9	13.8	(1)	(1)	15
9329	Ball Ground.	do.	Marble.	168	.28	7.7	5.2	11.2	2	31
4415	(2)	Coweta.	Diabase.	190	.21	2.3	17.4	(1)	(1)	8

1 Test not made.

2 Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

GEORGIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
9580	Newman (near)	Coweta	Diabase	Pounds. 190	Pounds. 36	2.4	17.0	18.7	28	17
9581	do.	do.	do.	190	40	2.2	18.2	19.3	37	31
421	Lithonia	De Kalb	Acid granite	168	12	4.8	8.3	(1)	(1)	9
9140	Stone Mountain Station.	do.	do.	162	16	5.3	7.5	(1)	(1)	15
5586	Atlanta	do.	Hornblende gneiss.	175	.83	5.1	7.9	16.8	6	26
9325	Stone Mountain 2	do.	Muscovite granite.	(1)	(1)	(1)	(1)	18.2	9	(1)
9326	Lithonia	do.	Granite.	165	14	4.6	8.7	18.5	5	18
9327	do.	do.	do.	165	36	5.1	7.8	18.3	3	19
9328	do.	do.	do.	165	24	4.5	8.9	18.3	4	14
9329	do.	do.	do.	165	25	3.4	9.1	18.5	6	12
9379	Stone Mountain	do.	Muscovite granite.	168	.15	3.0	13.1	(1)	(1)	9
416	New Elberton	do.	Granite.	(1)	(1)	(1)	(1)	18.4	9	(1)
7941	Ogleby	do.	Biotite granite.	168	18	6.1	6.6	13.5	4	48
8691	Rome	do.	Limestone	165	.34	2.8	14.3	13.9	16	17
9307	Atlanta (near).	Flord	Feldspathic quartzite.	162	.51	5.1	7.8	18.5	20	8
9321	do.	Fulton	do.	172	.32	3.5	11.4	18.8	11	25
9591	do.	do.	Schistose quartzite.	168	.24	4.0	10.0	17.5	10	9
7029	Atlanta (8 miles north of).	do.	Sericitic schist.	168	.58	6.4	6.2	17.7	7	16
9576	Atlanta (near).	do.	Biotite schist.	173	.26	5.4	7.4	13.5	16	26
9320	do.	do.	do.	173	.74	3.1	12.9	18.0	14	15
9133	do.	do.	Orthoclase biotite schist.	168	.71	8.6	4.7	(1)	(1)	12
9177	do.	do.	do.	168	.49	6.1	6.6	18.3	(1)	14
9180	do.	do.	Micro schist.	168	.52	4.3	8.7	17.7	6	19
9182	do.	do.	Hornblende schist.	178	.55	4.6	8.7	16.5	10	42
9185	do.	do.	Biotite schist.	178	.54	5.3	7.5	18.3	9	18
9195	do.	do.	Hornblende schist.	184	.43	6.5	7.2	17.7	13	25
9197	do.	do.	Hornblende epidote schist.	187	.24	5.3	7.6	17.7	9	27
9198	do.	do.	do.	187	.47	7.0	5.3	(1)	8	20
9302	do.	do.	Biotite schist.	168	1.59	7.6	5.7	18.3	(1)	39
9304	do.	do.	do.	172	.26	6.1	6.6	18.3	15	14
9308	do.	do.	do.	178	.32	3.5	11.4	18.0	4	26
9589	do.	do.	Biotite epidote schist.	178	.98	3.9	10.2	(1)	(1)	(1)
422	do.	do.	Hornblende gneiss.	187	.54	4.1	9.8	19.0	7	18
9142	do.	do.	Hornblende biotite gneiss	172	.54	4.1	9.3	18.5	9	12
9145	do.	do.	Biotite gneiss.	172	.54	4.3	9.3	18.5	9	20
9138	do.	do.	Granite gneiss.	172	.27	2.8	14.3	18.2	10	18
9139	do.	do.	do.	165	.39	3.2	12.5	18.3	7	18
9141	Atlanta (near).	do.	do.	165	1.00	4.3	9.3	18.3	5	18
9146	College Park.	do.	Biotite gneiss.	163	.62	10.5	9.3	17.0	4	25
9148	Atlanta (near).	do.	do.	165	.67	11.8	3.4	(1)	(1)	17

9151	do.	do.	172	50	5.6	7.1	18.5	6	16
9152	do.	do.	172	54	3.2	12.5	16.7	6	15
9153	do.	Granite gneiss	168	54	3.5	10.5	17.7	7	14
9154	do.	do.	168	71	4.5	8.9	18.0	7	13
9155	do.	Biotite gneiss	168	33	5.7	7.0	18.5	7	13
9156	do.	do.	168	33	3.4	11.8	18.3	10	13
9157	do.	do.	168	40	4.2	9.5	18.5	6	20
9175	do.	do.	172	72	4.2	12.1	18.7	13	18
9176	do.	Granite gneiss	168	40	3.3	12.1	18.7	6	14
9179	do.	do.	165	32	3.2	12.3	18.3	9	13
9181	do.	do.	168	32	2.9	13.6	18.7	6	13
9185	do.	Biotite gneiss	168	29	5.7	7.0	18.6	11	33
9186	do.	Granite gneiss	168	16	5.6	7.1	17.8	11	19
9187	do.	Hornblende gneiss	175	30	5.5	7.3	15.8	8	12
9188	do.	Biotite gneiss	184	16	5.1	7.8	(1)	(1)	15
9189	do.	do.	168	26	3.8	10.5	19.0	12	14
9190	do.	do.	175	31	7.6	5.3	(1)	(1)	34
9191	do.	do.	168	23	4.1	9.8	18.5	8	21
9192	do.	Granite gneiss	168	41	8.7	4.6	18.0	7	19
9193	do.	do.	165	72	3.9	10.3	18.5	7	39
9194	do.	Sericite gneiss	165	65	4.8	8.3	18.0	8	15
9196	do.	Granite gneiss	165	36	4.9	8.2	18.0	7	18
9200	do.	do.	168	31	3.9	10.2	18.3	11	20
9201	do.	do.	165	53	4.4	9.1	(1)	(1)	18
9298	do.	Biotite gneiss	175	50	12.9	3.1	17.8	9	24
9299	do.	do.	168	42	3.7	9.3	17.3	5	22
9300	do.	do.	165	42	3.7	10.8	17.8	11	15
9303	do.	Granite gneiss	168	39	4.8	8.3	(1)	(1)	19
9305	do.	Biotite gneiss	172	31	4.6	8.7	17.5	6	30
9306	do.	do.	168	51	3.8	10.5	15.7	9	24
9309	do.	Hornblende gneiss	172	16	6.6	2.9	18.2	6	20
9310	do.	Granite gneiss	168	25	4.1	9.3	18.0	7	17
9312	do.	Biotite gneiss	168	49	7.4	9.1	18.8	8	17
9318	do.	do.	175	53	7.4	5.3	17.5	10	13
9319	do.	do.	175	53	5.6	7.1	17.2	4	16
9322	do.	do.	172	19	5.6	7.1	17.5	5	26
9323	do.	do.	175	25	5.0	8.0	17.8	5	23
9324	do.	do.	175	45	6.9	5.8	18.7	6	23
9584	do.	Muscovite gneiss	165	38	6.5	6.2	17.8	8	23
9588	do.	Granite gneiss	165	42	4.4	9.1	18.7	7	20
9590	do.	Biotite gneiss	168	37	3.7	10.8	17.3	5	23
9314	do.	Granite	168	35	4.1	9.8	18.3	6	16
9137	do.	Biotite granite	172	39	5.1	7.9	17.7	6	17
9143	do.	Granite	165	50	4.8	8.3	18.3	7	14
9144	do.	Biotite granite	168	28	7.7	5.5	18.5	7	22
9147	do.	do.	165	32	8.6	4.7	17.0	4	15
9149	do.	do.	168	57	7.4	5.3	14.6	5	15
9150	do.	do.	165	21	3.4	11.8	18.7	16	27
9163	do.	Granite	168	33	4.8	8.3	17.2	5	26
9184	do.	Biotite granite	162	52	7.2	5.6	17.7	5	14
9199	do.	Muscovite granite							

1 Test not made.

2 Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

GEORGIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
9301	Atlanta (near).....	Fulton.	Granite porphyry.....	139	2.39	6.9	5.8	(1)	(1)	68
9311	Atlanta.....	do.	Granite.....	168	.25	6.8	5.9	17.7	5	12
9313	Atlanta (near).....	do.	Biotite granite.....	165	.31	6.8	3.9	18.5	3	15
9315	do.....	do.	Weathered granite.....	165	1.13	13.4	3.0	14.3	5	21
9392	Atlanta.....	do.	do.....	(1)	(1)	(1)	(1)	18.3	8	(1)
93100	do.....	do.	do.....	(1)	(1)	(1)	(1)	18.3	8	(1)
9316	Atlanta (near).....	do.	Biotite granite.....	168	.38	7.3	5.5	17.3	4	20
9317	do.....	do.	do.....	165	.60	12.8	3.1	15.0	4	23
9374	do.....	do.	do.....	165	.68	5.1	7.8	18.7	5	19
9375	do.....	do.	do.....	165	.43	3.1	12.9	18.5	9	25
9382	do.....	do.	do.....	168	.31	5.0	8.0	19.0	8	20
9383	do.....	do.	Granite.....	162	.53	7.8	5.1	19.0	5	10
9385	do.....	do.	Gneissoid granite.....	162	.69	7.9	5.1	(1)	(1)	34
9386	do.....	do.	Altered granite porphyry.....	168	.62	8.1	4.9	17.7	6	21
9387	do.....	do.	Biotite granite.....	168	.28	6.4	6.3	19.0	7	27
38	do.....	do.	do.....	(1)	(1)	4.8	8.4	(1)	(1)	(1)
1639	Gainesville.....	Gordon.	Chert.....	178	.26	13.7	5.7	13.7	7	57
1640	do.....	Hall.	Dolomitic marble.....	178	.21	7.0	9.9	9.6	5	27
1641	do.....	do.	do.....	175	.52	6.7	6.0	13.8	4	38
2469	do.....	do.	do.....	(1)	(1)	(1)	(1)	19.3	11	10
2470	do.....	do.	Granite gneiss.....	(1)	(1)	(1)	(1)	18.2	8	11
2471	do.....	do.	do.....	(1)	(1)	(1)	(1)	15.5	6	26
9203	Cataula.....	do.	Mica schist.....	172	.27	4.5	8.9	17.8	7	17
9204	do.....	Harris.	Biotite gneiss.....	165	.26	4.6	8.7	18.7	6	20
9331	do.....	do.	Granite gneiss.....	162	.98	2.6	15.3	19.0	7	9
9333	Stockbridge (2 miles from).....	Henry.	Granite.....	162	.57	6.8	5.9	19.2	7	20
9336	do.....	do.	do.....	168	.36	6.5	6.2	18.3	6	11
420	do.....	do.	do.....	187	.42	2.6	15.2	(1)	4	10
9328	Roberts Station.....	Jones.	Diabase.....	162	.31	7.7	5.2	18.0	(1)	18
9578	Harris City (2 miles from).....	Merriwether.	Granite.....	165	.47	3.5	11.4	18.7	4	21
8118	Greenville (near).....	do.	do.....	168	.26	5.1	7.7	18.0	6	21
9334	Holton (near).....	Bibb.	Biotite gneiss.....	184	.37	6.1	6.5	16.5	4	12
9332	Juliette (3 mile north of).....	Monroe.	Hornblende gneiss.....	168	.39	2.3	17.4	18.0	15	27
9335	Paeah Quarry.....	do.	Quartzite.....	165	.23	3.9	10.3	17.8	5	12
9339	do.....	do.	Aplitic granite.....	162	.89	5.9	6.8	(1)	(1)	12
9539	Covington (near).....	Newton.	Biotite granite.....	162	.85	9.1	4.4	18.5	4	12
9540	Oxford (near).....	do.	Granite.....	165	.55	8.1	4.9	(1)	(1)	15
9541	do.....	do.	do.....	165	.63	4.0	10.0	18.2	7	14
9542	Covington.....	do.	Gneissoid granite.....	165	.63	10.5	3.8	(1)	(1)	37
9543	Covington (near).....	do.	Altered rhyolite.....	162	1.25	(1)	(1)	(1)	(1)	(1)

9019	Tate.....	Pickens.....	Marble.....	168	.34	10.2	3.9	12.7	4	29
9020	do.....	do.....	do.....	168	.48	(1)	(1)	8.7	4	29
9330	do.....	do.....	do.....	172	.26	12.3	3.1	12.0	4	21
6918	Portland.....	Polk.....	Siliceous limestone.....	172	.19	3.5	11.6	17.1	10	33
8657	Rock Mart.....	do.....	Dolomitic limestone.....	178	.23	3.4	11.6	15.7	10	45
8658	Portland.....	do.....	Limestone.....	172	.26	4.5	9.0	(1)	(1)	(1)
419	Augusta (near).....	Richmond.....	Granite gneiss.....	165	.37	2.6	15.4	(1)	(1)	(1)
3733	Conyers.....	Rockdale.....	Biotite gneiss.....	165	.24	4.4	9.1	18.6	9	14
9503	Conyers (near).....	do.....	do.....	165	.28	5.8	6.9	18.0	4	24
9500	do.....	do.....	Granite.....	165	.40	5.4	7.4	(1)	(1)	15
9501	do.....	do.....	Gneissoid granite.....	165	.51	5.7	7.0	18.7	3	19
9502	do.....	do.....	Granite.....	165	.68	4.7	8.5	18.7	5	11
9504	do.....	do.....	do.....	162	.64	4.5	8.9	18.3	3	11
do.....	do.....	do.....	do.....	162	.52	3.7	10.8	18.7	3	9
9505	do.....	do.....	do.....	162	.18	5.2	7.7	(1)	(1)	(1)
468	Toccoa.....	Stevens.....	Gneiss.....	162	.35	3.8	10.6	(1)	(1)	86
413	do.....	Walker.....	Limestone.....	162	3.42	27.9	1.4	(1)	(1)	6
414	(2).....	do.....	Chert.....	143	3.70	16.4	2.4	(1)	(1)	(1)
418	(2).....	do.....	do.....	187						

IDAHO.

1261	Boise.....	Ada.....	Rhyolite.....	134	5.87	6.1	6.6	15.3	6	14
1263	do.....	do.....	Basalt.....	172	1.88	7.6	5.3	18.1	9	8
1264	do.....	do.....	do.....	180	1.02	2.7	14.9	14.9	12	500+
6102	Pocatello (2 miles southeast of).....	Bannock.....	Olivine basalt.....	178	1.44	4.8	8.4	16.3	11	7
6103	Pocatello (7 miles southeast of).....	do.....	Feldspathic sandstone.....	168	.74	(1)	(1)	16.7	6	9
6164	Pocatello (1 mile southeast of).....	do.....	Feldspathic quartzite.....	165	.31	3.1	12.7	19.2	9	2
4394	Coeur d'Alene.....	Kootenai.....	Basalt.....	178	.98	2.1	19.0	19.0	32	6
1271	Moscow.....	Lathia.....	do.....	153	5.14	7.7	5.2	5.9	6	464
1273	do.....	do.....	do.....	178	1.41	4.6	8.7	(1)	(1)	27

ILLINOIS.

1522	Quincy.....	Adams.....	Limestone.....	165	1.66	7.6	5.3	10.6	6	46
2396	do.....	do.....	do.....	168	1.01	6.0	6.0	13.2	6	37
2397	do.....	do.....	Limestone and chert.....	168	.51	3.3	7.8	12.7	5	67
437	Elco.....	Alexander.....	Chert.....	156	3.30	3.9	6.8	(1)	(1)	12
584	do.....	do.....	do.....	150	4.13	2.7	14.0	(1)	(1)	5
1443	Ulin (near).....	do.....	do.....	162	.50	3.8	6.9	19.4	7	15
7148	Olive Branch.....	do.....	do.....	150	1.69	12.0	3.3	(1)	(1)	(1)
7213	Brookville (near).....	Ogle.....	Argillaceous dolomite.....	172	.82	6.4	6.3	10.6	3	64
7421	do.....	do.....	do.....	165	2.64	3.4	7.4	15.0	7	105
7422	do.....	do.....	do.....	165	3.45	6.1	6.6	14.2	5	67
7423	do.....	do.....	do.....	165	2.70	5.2	7.6	13.6	7	74
2391	Marshall.....	Clark.....	Limestone.....	165	.91	3.7	10.8	14.8	5	31

¹ Test not made.² Exact locality not known.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.*

ILLINOIS—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
2392	Casey.....	Clark.....	Limestone.....	Pounds. 168	Pounds. .68	5.2	7.7	15.7	4	33
5846	do.....	do.....	do.....	168	.64	4.8	8.3	15.0	4	49
4422	Embaras.....	Coles.....	do.....	168	1.42	4.2	9.5	14.2	6	40
7615	Loxa.....	do.....	Argillaceous limestone.....	168	.43	4.8	8.3	15.0	7	38
716	Chicago.....	Cook.....	Dolomite.....	168	.58	4.4	9.1	(1)	(1)	30
756	do.....	do.....	do.....	168	.86	5.8	6.6	15.1	(1)	(1)
4126	(?).....	do.....	do.....	172	.84	6.0	6.6	15.1	8	34
5509	Thornton.....	do.....	Siliceous dolomite.....	162	2.15	4.9	8.2	13.5	6	16
5755	do.....	do.....	Dolomite.....	156	4.44	5.3	7.5	13.0	6	128
6053	do.....	do.....	Dolomite.....	172	1.02	6.1	6.6	12.7	7	24
7737	(?).....	do.....	do.....	168	.88	5.1	7.9	16.0	11	37
7739	Bellewood.....	do.....	Argillaceous dolomite.....	168	2.11	4.5	8.9	15.8	9	26
7754	Thornton.....	do.....	Dolomite.....	168	1.68	4.5	8.9	13.9	10	27
7764	Chicago.....	do.....	do.....	172	.76	4.8	8.3	15.8	10	40
7768	do.....	do.....	do.....	168	.99	4.2	9.5	13.8	7	34
7783	do.....	do.....	do.....	168	1.59	6.5	6.1	16.0	6	32
8069	La Grange.....	do.....	do.....	162	1.53	4.9	8.1	13.0	6	46
8147	(?).....	do.....	Argillaceous dolomite.....	162	3.97	4.2	9.5	14.7	4	110
8711	Hillside.....	do.....	Blast-furnace slag.....	(1)	(1)	12.7	3.1	15.8	3	33
2165	Chicago.....	do.....	do.....	(1)	(1)	12.7	3.1	14.8	3	156
2166	do.....	do.....	do.....	(1)	(1)	9.4	3.0	15.0	8	11
2167	do.....	do.....	do.....	(1)	(1)	33	3.0	17.5	(1)	16
2316	do.....	do.....	Slag.....	178	.56	4.7	8.5	6.5	4	52
8097	do.....	do.....	Limestone.....	168	(1)	(1)	(1)	18.1	16	(1)
5929	Chicago.....	do.....	Altered andesite.....	162	1.64	9.1	4.4	14.2	6	32
2678	Naperville.....	Dupage.....	Dolomite.....	165	.34	4.6	8.7	17.0	8	40
5798	Elmhurst.....	do.....	Argillaceous dolomite.....	168	1.02	5.4	7.4	13.7	6	34
2389	Paris.....	Edgar.....	Limestone.....	168	.88	5.3	7.5	15.2	6	35
2390	do.....	do.....	do.....	168	.69	6.6	6.0	15.7	8	30
2424	Cherrypoint.....	do.....	do.....	168	.67	9.2	4.3	16.0	8	36
6370	Gillmore.....	Effingham.....	do.....	159	4.89	8.0	5.0	8.7	4	36
2401	Pontiac.....	Hancock.....	Argillaceous limestone.....	159	3.71	6.5	6.2	17.2	4	40
2402	Hamilton.....	do.....	Limestone.....	159	3.71	6.5	6.2	17.2	5	61
2400	Gladstone.....	do.....	do.....	162	1.36	9.1	4.4	9.7	5	42
3258	Biggsville.....	Henderson.....	do.....	162	2.45	4.9	8.2	18.1	6	67
9228	Grafton.....	do.....	Argillaceous dolomite.....	159	3.68	6.1	6.6	12.5	5	26
9229	do.....	do.....	do.....	156	2.07	7.7	5.2	12.7	4	25
9230	do.....	do.....	do.....	162	1.83	7.1	5.6	16.5	4	14
452	(?).....	do.....	do.....	168	1.80	13.1	9.1	(1)	(1)	(1)
452	Tunnell Hill.....	Jo Davess.....	Limestone.....	168	2.92	4.4	10.5	15.9	6	(1)
4660	do.....	Johnson.....	Sandstone.....	150	2.92	4.4	10.5	15.9	20	73
6598	Vienna (near).....	do.....	Argillaceous limestone.....	165	.73	3.8	10.5	17.8	20	73

7007	Whitehill.	do.	Fossiliferous limestone.	168	.34	6.8	5.9	13.9	4	51
7303	Reevesville.	do.	Argillaceous limestone.	168	.27	5.1	7.8	13.7	6	53
7510	do.	do.	do.	168	.34	9.7	9.7	16.3	6	53
7617	Cypress.	do.	do.	168	.59	3.9	10.2	13.2	7	21
2638	Batavia.	Kane.	Limestone.	172	1.06	4.9	8.2	13.1	7	49
2543	Aurora.	do.	Slag.	218	.62	2.7	14.6	18.0	20	4
8464	do.	do.	Smelter slag.	218	.47	2.8	14.2	18.0	20	4
5046	Batavia.	do.	Dolomite.	165	3.14	6.3	6.4	12.1	9	26
5087	do.	do.	do.	165	3.44	5.3	7.5	13.9	8	32
5087	do.	do.	do.	165	2.44	4.3	9.4	15.4	9	29
7558	Elgin.	do.	do.	172	1.61	4.3	9.3	16.0	39	(1)
7558	do.	do.	do.	168	2.48	4.4	9.2	12.9	7	7
5550	Kankakee.	do.	do.	165	2.30	6.9	5.8	13.3	5	5
do.	do.	do.	Argillaceous dolomite.	172	1.56	4.5	8.9	15.2	9	12
6068	do.	do.	Dolomite.	162	3.71	5.7	7.0	13.0	4	14
6165	do.	do.	Argillaceous dolomite.	168	2.97	9.0	4.4	11.7	5	33
6443	do.	do.	Dolomite.	162	1.73	6.0	6.7	13.8	4	57
6865	do.	do.	do.	159	2.24	7.2	5.6	9.0	6	28
7023	do.	do.	Argillaceous dolomite.	165	3.28	5.3	7.5	9.2	6	22
7025	Lehigh (near).	do.	Dolomite.	170	1.04	7.7	5.2	14.0	8	9
7026	Tucker (near).	do.	do.	172	.84	7.2	5.6	14.0	4	17
7027	Monteno (near).	do.	do.	162	1.29	6.5	6.2	9.5	4	17
7028	Kankakee.	do.	do.	168	2.76	5.2	7.7	13.2	7	17
7029	Boufield.	do.	do.	165	2.82	6.0	6.7	11.3	4	4
7071	Kankakee.	do.	do.	165	3.31	6.8	5.9	10.7	5	25
7072	do.	do.	Argillaceous dolomite.	168	1.89	4.8	8.3	14.3	10	44
7298	do.	do.	do.	165	3.23	4.9	8.1	13.9	7	58
7300	do.	do.	Dolomite.	168	7.00	4.5	8.8	14.5	6	43
7301	do.	do.	do.	162	2.28	7.3	7.3	14.3	9	28
7302	do.	do.	do.	162	1.86	7.0	5.7	14.5	7	77
7525	Lehigh.	do.	Argillaceous dolomite.	162	4.98	5.2	7.7	10.8	6	43
7525	do.	do.	Dolomite.	165	3.05	4.2	9.5	13.8	4	36
7736	Kankakee.	do.	do.	168	1.39	3.8	8.4	13.5	7	144
7871	Lehigh.	do.	Argillaceous dolomite.	168	2.23	3.7	10.7	14.7	7	7
787	Streator.	Lasalle.	Sandstone.	159	2.20	21.0	1.9	(1)	(1)	144
8664	Lee.	do.	Dolomite.	172	1.38	4.7	8.4	16.7	4	69
9509	do.	do.	Argillaceous limestone.	168	1.96	8.5	4.7	(1)	(1)	69
do.	Alton.	Madison.	Limestone.	168	.82	5.7	7.1	14.0	7	38
(2)	do.	do.	do.	168	.77	3.4	11.8	16.0	6	38
8145	do.	Monroe.	do.	162	3.42	2.8	6.7	14.4	6	49
(2)	Hillsboro.	do.	do.	172	2.00	6.0	6.7	14.4	(1)	44
8146	do.	Montgomery.	Chert.	150	5.67	17.1	2.3	(1)	(1)	23
1585	Oregon.	Ogle.	Limestone.	165	1.73	4.0	10.1	16.0	5	8
2393	Princetonville.	Peoria.	do.	165	1.48	5.0	8.0	13.5	8	56
2394	Maxwell.	do.	do.	162	1.71	5.3	7.6	10.7	(1)	(1)
2395	do.	do.	do.	156	3.79	3.8	10.4	14.0	6	87

Exact locality not known.

Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

ILLINOIS—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
770	Smithton.....	St. Clair.....	Limestone.....	Pounds. 168	Pounds. .30	4.4	9.2	(1)	(1)	(1) 88
786	do.....	do.....	do.....	168	.17	5.9	6.8	(1)	(1)	5
7214	Columbia.....	do.....	do.....	162	2.56	3.4	11.6	11.9	(1)	81
7622	Stolle.....	do.....	do.....	168	.28	4.3	9.2	14.7	(1)	48
7734	East St. Louis.....	do.....	do.....	168	.47	4.3	9.4	14.3	(1)	23
8148	(2).....	do.....	do.....	168	.72	3.0	13.2	16.7	(1)	69
7652	Winchester.....	Scott.....	Argillaceous limestone.....	172	.65	5.6	7.1	14.5	(1)	3
6083	Kalamazoo.....	Thornorton.....	Dolomite.....	165	1.56	5.5	7.3	13.7	(1)	20
3225	Anna.....	Union.....	Limestone.....	168	.61	4.2	9.5	(1)	(1)	54
5549	do.....	do.....	do.....	168	.42	3.3	12.0	14.3	(1)	15
7623	do.....	do.....	do.....	165	1.08	5.0	8.1	15.3	(1)	16
2388	Fairmount.....	Vermilion.....	do.....	165	1.20	5.1	7.9	14.0	(1)	58
1298	Joliet.....	Will.....	Dolomite.....	168	2.58	4.3	9.4	12.9	(1)	40
2774	do.....	do.....	do.....	165	1.33	5.8	6.9	15.4	(1)	35
2775	do.....	do.....	do.....	165	1.75	5.2	7.7	15.0	(1)	27
2776	do.....	do.....	do.....	172	2.87	4.7	8.4	15.7	(1)	23
2777	do.....	do.....	do.....	168	2.21	4.7	8.5	14.3	(1)	43
2773	do.....	do.....	Chert.....	153	3.84	7.1	5.6	19.2	(1)	74
8075	(2).....	do.....	Dolomite.....	165	.76	10.3	3.9	13.8	(1)	16
7374	Cook.....	do.....	Argillaceous dolomite.....	162	4.65	4.7	8.5	11.3	(1)	100

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1346	Pleasant Mills.....	Adams.....	Dolomitic limestone.....	159	3.56	10.2	3.9	(1)	(1)	22
7744	Fort Wayne.....	Allen.....	Hornblende granite.....	168	.50	2.4	16.7	(1)	(1)	20
1382	Hope.....	Bartholomew.....	Limestone.....	172	1.71	5.0	6.7	10.2	(1)	41
1384	Burnsville.....	do.....	do.....	165	.97	6.0	6.7	7.3	(1)	25
1416	Grammer.....	do.....	do.....	159	1.37	6.9	6.5	14.8	(1)	52
1378	Montpelier.....	do.....	do.....	165	2.97	3.7	16.2	(1)	(1)	28
2077	do.....	Blackford.....	Dolomitic limestone.....	172	1.19	9.3	12.1	14.8	(1)	16
9342	Hartford.....	do.....	Dolomite.....	168	2.78	.75	7.9	13.3	(1)	42
1206	Delph.....	do.....	Dolomitic limestone.....	172	.50	5.7	7.9	16.2	(1)	14
1344	Washington.....	Carroll.....	Limestone.....	172	.40	3.1	7.8	13.8	(1)	30
5334	Logansport.....	do.....	do.....	168	.20	9.1	4.4	14.0	(1)	31
2951	do.....	Cass.....	Cherty limestone.....	168	.53	4.1	9.8	16.1	(1)	47
3965	do.....	do.....	Dolomite.....	168					(1)	9

1457	Charlestown	Clark	Limestone	162	1.41	5.6	7.1	12.8	8	52
1458	Jeffersonville	do.	Dolomitic limestone	165	1.23	3.4	11.7	12.5	7	99
1459	Milton	Crawford	Limestone	168	.55	3.6	11.2	12.7	8	91
1460	Marengo	do.	do.	168	.36	4.9	8.2	13.3	10	99
1461	Milltown	do.	do.	168	.49	3.9	10.3	13.5	7	26
1462	do.	do.	Dolomitic limestone	165	.46	3.4	11.6	15.5	8	95
1463	Marengo	do.	Limestone	165	1.61	3.7	10.8	15.0	9	53
1464	Dillsboro	do.	do.	168	.78	4.8	8.3	15.4	7	100
1465	Dearborn	do.	do.	168	.62	4.8	8.3	12.1	8	59
1466	Wasburg	do.	do.	172	.93	3.5	11.3	15.0	10	34
1467	Newpoint	Decatur	do.	159	2.99	4.7	8.5	11.3	9	38
1468	Greensburg	do.	do.	172	1.27	4.5	9.0	16.4	8	56
1469	do.	do.	do.	168	.88	4.2	9.5	13.2	7	19
1470	St. Paul	do.	Crystalline limestone	168	.86	3.6	11.2	13.8	7	16
1471	do.	do.	Limestone	159	3.23	8.3	4.8	(1)	5	(1)
1472	do.	do.	Siliceous limestone	168	1.58	5.1	7.8	14.3	6	(1)
1473	do.	do.	Limestone	168	1.14	7.4	8.3	14.7	6	(1)
1474	do.	do.	Dolomitic limestone	168	.68	7.4	8.3	13.2	6	(1)
1475	do.	do.	do.	175	.74	4.8	8.3	14.9	6	(1)
1476	Delaware	do.	Dolomite	162	1.51	5.6	7.1	14.6	6	18
1477	do.	do.	do.	165	2.06	4.3	9.3	16.3	13	24
1478	do.	do.	Dolomitic limestone	165	.85	3.9	10.4	15.0	10	119
1479	Dubois	do.	Limestone	172	1.79	3.7	10.8	16.0	11	84
1480	do.	do.	do.	168	.68	3.5	11.3	15.3	7	70
1481	Joinsburg	do.	do.	165	1.60	(1)	(1)	15.0	11	41
1482	Jasper (near)	do.	do.	165	1.21	3.8	10.5	15.0	9	8
1483	do.	do.	do.	165	1.32	4.4	9.0	13.0	9	114
1484	Edwardsville (near)	Floyd	do.	156	2.83	3.0	13.5	(1)	7	115
1485	Africa (6 miles northeast of)	Fountain	Chert	163	1.90	3.6	11.1	16.3	(1)	10
1486	Veedersburg	do.	Argillaceous limestone	165	1.45	(1)	(1)	13.0	10	28
1487	Marion	Grant	do.	165	1.45	5.2	7.8	12.4	15	56
1488	do.	do.	Limestone	159	4.72	4.72	13.8	16.8	10	66
1489	Bloomfield (6 miles northeast of)	Greene	do.	168	1.15	3.0	13.2	17.1	30	26
1490	Noblesville	Hamilton	Dolomite	172	1.97	4.9	8.1	17.1	11	131
1491	Corydon (near)	Harrison	Dolomitic limestone	156	1.08	4.5	8.8	17.3	9	39
1492	do.	do.	Limestone	168	.52	3.7	10.9	16.7	9	4
1493	do.	do.	Argillaceous dolomite	143	9.40	8.6	4.7	1.8	4	74
1494	Kokomo (near)	do.	Dolomitic limestone	153	6.50	4.1	9.7	13.8	17	42
1495	do.	Howard	Limestone	153	6.21	4.2	9.6	11.6	8	63
1496	do.	do.	do.	168	.27	5.8	6.9	15.2	6	23
1497	Huntington	do.	do.	168	.57	6.9	3.8	14.4	8	34
1498	do.	Huntington	Cherty limestone	165	1.06	6.0	6.7	15.0	8	39
1499	do.	do.	Dolomite	162	3.98	5.7	7.0	12.3	6	46
1500	do.	do.	do.	172	.54	6.0	6.7	15.1	8	40
1501	Markle	do.	do.	168	1.27	14.2	2.8	14.3	5	23
1502	do.	do.	do.	168	.79	6.7	6.0	13.3	6	23
1503	do.	do.	Siliceous dolomite	165	3.20	4.5	9.9	9.9	43	43
1504	do.	do.	do.	165	4.40	4.6	8.7	12.0	10	151
1505	do.	do.	do.	165	3.29	5.1	7.8	16.8	14	37
1506	Jackson	do.	Dolomite	168	.69	7.0	5.7	13.0	8	45
1507	Jay	do.	do.	159	3.58	12.3	3.2	4.4	7	45
1508	Portland	Jefferson	do.	165	3.21	5.2	7.8	12.3	12	53
1509	Hanover	do.	Limestone	165						
1510	North Madison	do.	do.	165						

¹ Test not made.

Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916—Contd.

INDIANA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
1413	Deputy	Jefferson	Limestone	Pounds. 168	Pounds. .43	4.7	8.5	10.9	7	81
4699	do.	do.	do.	168	.46	5.0	8.1	15.3	9	(1)
1458	Bewersville	Jennings	do.	168	.93	3.2	12.6	14.4	9	97
1488	North Vernon	do.	Dolomitic limestone	168	.57	3.7	10.9	13.8	8	94
4702	do.	do.	do.	162	3.79	3.4	10.1	14.9	8	(1)
515	Freelandville	Knox	Limestone	172	.65	3.8	10.6	(1)	(1)	42
540	Bicknell	do.	Dolomitic limestone	168	.90	3.8	10.1	(1)	(1)	47
588	Freelandville	do.	Arcaceous dolomite	175	1.36	2.5	10.1	(1)	(1)	179
4197	Mitchel	Lawrence	Arcaceous dolomite	163	5.77	8.1	8.0	2.7	4	75
1423	do.	do.	Limestone	162	1.66	4.6	8.8	13.0	6	26
1489	Williams (near)	do.	Dolomitic limestone	168	3.70	4.1	8.7	16.4	6	(1)
4697	Pedford	do.	Limestone	139	3.08	6.2	8.4	10.3	6	151
4698	Lawrenceport	do.	do.	156	2.46	13.3	8.7	10.3	3	(1)
5027	Pedford	do.	do.	136	6.4	6.2	6.9	8.5	4	13
5028	do.	do.	do.	163	7.76	4.2	7.3	13.3	2	38
5029	do.	do.	do.	136	2.42	7.6	7.3	14.6	2	20
1379	Ingalls	Madison	do.	168	.29	5.6	9.3	11.8	7	38
1380	Alexandria	do.	do.	165	1.41	4.3	9.2	14.5	5	30
1381	Frankton	do.	do.	163	1.57	4.4	9.2	14.5	5	28
1714	Ingalls	do.	do.	168	.41	5.8	6.9	14.5	6	32
1715	do.	do.	do.	168	1.35	5.8	6.9	10.7	5	53
Anderson	do.	do.	do.	168	4.41	4.5	8.9	17.0	4	39
4752	do.	do.	do.	168	2.00	3.2	12.4	14.9	9	67
1459	Sholas (near)	Martin	do.	162	2.73	3.6	12.4	14.2	14	(1)
994	Ferru	Miami	Dolomite	173	1.73	3.6	11.5	15.8	12	74
1463	Bloomington	Monroe	Limestone	162	2.16	3.5	11.5	15.8	12	63
1464	do.	do.	do.	130	4.44	10.8	3.7	0	4	49
1465	do.	do.	do.	165	3.32	10.6	3.8	3.9	6	62
1466	do.	do.	do.	165	.97	3.3	7.5	9.7	13	41
1467	do.	do.	Dolomitic limestone	165	1.70	3.0	13.4	15.2	5	29
8181	do.	do.	Limestone	168	4.49	4.9	8.1	15.2	5	(1)
9450	Victor	do.	do.	162	1.85	9.9	4.1	11.8	5	43
1386	Waveland	Montgomery	do.	160	1.98	3.9	12.2	8.7	5	33
1348	Kentland (near)	Newton	do.	160	.33	4.1	9.7	16.4	12	33
8761	do.	do.	do.	168	.64	3.8	10.5	14.8	5	25
6454	Petersburg	Pike	Carbonaceous limestone	175	1.43	2.7	13.0	17.2	20	66
2982	do.	do.	Siliceous limestone	165	2.23	4.4	9.0	18.8	6	80
2980	do.	do.	Sandstone, ferruginous	150	3.59	39.0	1.0	0	2	69
2981	do.	do.	Feldspathic sandstone	147	6.28	10.7	3.7	0	5	124
1461	do.	do.	Calcareous shale	172	.81	4.9	8.1	.2	9	71

1409	Rising Sun.....	Ohio.....	Limestone.....	168	46	5.5	7.3	13.1	9	13
1462	Oreans.....	Orange.....	do.....	159	3.00	4.4	9.1	14.8	5	98
516	Spencer.....	Owen.....	do.....	159	4.5	4.5	11.5	(1)	5	78
1341	Spencer (near).....	do.....	do.....	168	3.5	3.5	8.5	13.8	17	21
1422	Spencer.....	do.....	do.....	168	3.88	3.7	10.9	13.8	9	45
1493	Mount Vernon.....	Posey.....	Dolomitic limestone.....	162	3.00	3.4	11.8	16.2	8	108
1492	do.....	do.....	do.....	168	1.67	3.5	21.7	15.4	8	56
1210	Greencastle.....	Putnam.....	Limestone.....	165	1.12	3.9	10.3	13.9	8	70
1343	Greencastle (near).....	do.....	do.....	168	7.9	3.9	10.3	17.3	11	24
1347	Greencastle.....	do.....	do.....	165	1.53	4.5	8.9	15.5	8	20
2111	do.....	do.....	do.....	168	5.3	4.2	9.5	15.0	7	45
2112	do.....	do.....	do.....	168	7.9	3.4	11.6	13.0	8	79
3368	do.....	do.....	do.....	168	.59	3.2	12.5	15.8	11	46
1212	Oakalla.....	do.....	do.....	168	.52	3.2	12.5	14.2	12	29
1345	Russellville.....	do.....	do.....	165	.99	4.4	9.0	13.7	9	72
1342	Greencastle.....	do.....	do.....	168	.43	4.3	9.2	12.9	7	22
5869	Ridgeville.....	Randolph.....	Dolomite.....	165	1.77	7.7	5.2	14.3	7	25
1350	do.....	do.....	Dolomitic limestone.....	165	.77	7.2	5.6	16.7	6	19
1659	do.....	do.....	Dolomite.....	168	2.11	8.7	4.6	16.7	9	10
4701	Osgood.....	Ripley.....	do.....	168	.62	5.0	8.0	13.5	7	(1)
4700	Holton.....	do.....	Dolomitic limestone.....	168	.89	4.6	8.6	12.9	6	(1)
5565	do.....	do.....	Limestone.....	168	.64	4.0	10.0	13.7	8	24
5737	Osgood.....	do.....	do.....	168	1.06	8.1	5.0	13.7	9	56
1438	New Salem.....	Rush.....	Dolomite.....	162	2.33	12.7	3.1	13.0	5	24
1410	Rushville.....	do.....	Limestone.....	168	2.18	2.7	14.8	8.6	6	63
1456	Lexington.....	Scott.....	do.....	165	2.97	2.3	12.3	19.2	9	103
2005	Waldron.....	Shelby.....	do.....	162	2.57	4.2	9.5	17.7	5	52
2008	Shelbyville.....	do.....	do.....	162	2.53	5.6	7.2	15.7	11	60
2007	do.....	do.....	do.....	168	1.82	4.0	10.0	11.7	7	60
9135	Sullivan.....	do.....	Argillaceous limestone.....	165	1.36	3.8	10.5	15.2	9	60
1411	Soapville.....	Switzerland.....	Limestone.....	168	.80	4.0	10.0	11.1	9	20
1415	Vevay.....	do.....	do.....	168	.87	5.4	7.5	12.8	8	38
1494	Evansville.....	Vanderburg.....	Dolomitic limestone.....	168	1.38	4.0	10.0	15.8	46	46
1349	Wabash.....	do.....	Limestone.....	159	2.43	4.6	8.7	40	52	40
1390	do.....	do.....	do.....	162	3.29	3.8	10.5	15.3	27	27
1391	do.....	do.....	Dolomitic limestone.....	172	2.43	3.3	12.1	16.0	9	9
1647	do.....	do.....	Limestone.....	165	1.10	4.3	9.3	15.0	6	15
1647	do.....	do.....	do.....	168	.87	3.9	10.2	14.5	6	(1)
4657	do.....	do.....	Calcareous sandstone.....	156	5.10	7.0	5.7	17.2	11	142
880	Williamsport.....	Warren.....	Dolomitic limestone.....	168	.97	3.3	12.3	10.7	7	126
1460	Roanville.....	Warren.....	do.....	162	2.00	5.2	7.7	10.7	4	57
6773	Washington.....	Washington.....	Argillaceous dolomite.....	172	1.26	5.7	7.0	15.2	41	41
6876	Wayne.....	do.....	Limestone.....	168	.89	4.5	8.9	15.8	6	28
1385	do.....	do.....	do.....	172	1.65	6.3	6.3	15.8	37	37
1377	Bluffton.....	Wells.....	Dolomite.....	172	1.59	5.8	6.9	17.0	8	29
1387	do.....	do.....	do.....	168	1.80	6.9	5.8	16.4	4	27
6872	do.....	do.....	Argillaceous dolomite.....	168	1.04	5.3	7.7	14.3	9	27
1469	Monon.....	White.....	Dolomitic limestone.....	168	1.43	11.9	(1)	7.7	9	40
9007	Columbia.....	Whitley.....	Limestone.....	168	1.53	5.2	8.7	17.0	8	35
9008	do.....	do.....	Argillaceous dolomite.....	172	1.29	4.6	8.7	17.0	8	35

Exact locality not known.

Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

IOWA.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
462	Raymond.	Black Hawk.	Dolomite.	Pounds. 168	Pounds. 0.64	4.5	8.9	(1)	(1)	161
8912	Mason.	Cerro Gorda.	Limestone.	168	1.62	6.0	6.7	13.0	2	(1)
8914	do.	do.	do.	165	1.53	5.7	7.1	13.0	3	(1)
8913	do.	do.	Dolomite.	175	1.12	3.8	10.5	13.7	6	(1)
455	Poeata.	Dubuque.	do.	159	3.30	11.6	2.7	(1)	(1)	32
7704	do.	do.	Argillaceous dolomite.	171	1.59	14.6	2.7	13.6	6	42
7855	Farley (near).	do.	do.	168	4.13	11.3	3.5	5.1	7	45
7858	(2)	do.	do.	168	2.10	10.2	3.9	13.7	7	15
7859	Stone City.	do.	Dolomite.	(1)	(1)	7.6	5.2	(1)	(1)	24
7860	(2)	do.	Argillaceous dolomite.	173	.95	5.8	6.9	14.0	5	28
7854	(2)	do.	Argillaceous limestone.	168	1.30	13.8	2.9	10.8	4	22
7856	(2)	do.	do.	165	3.10	6.5	6.2	12.0	5	37
7857	do.	do.	do.	165	2.60	(1)	(1)	5.2	3	36
8922	Dubuque.	do.	do.	172	1.57	4.7	8.6	13.7	9	32
5972	Ballenger.	Lee.	Limestone.	162	2.17	5.5	7.3	9.2	4	24
5525	Cedar Rapids.	Linn.	Dolomitic limestone.	172	1.34	6.7	6.0	16.8	11	30
6102	do.	do.	Dolomite.	156	3.81	14.9	2.7	(1)	3	17
6103	do.	do.	Limestone.	168	1.64	4.6	8.8	10.0	8	18
5973	Peru.	Madison.	do.	165	1.55	4.6	8.7	15.6	8	29
5526	La Grande.	Marshall.	do.	165	2.14	4.6	8.7	15.3	6	56
7121	Buffalo.	Muscatine.	do.	165	2.50	5.1	7.9	(1)	(1)	45
383	Butterville.	Tama.	Argillaceous limestone.	162	3.23	21.9	1.8	(1)	(1)	(1)
384	Montcur.	do.	Dolomitic limestone.	162	1.65	6.7	5.9	(1)	(1)	(1)

KANSAS.

1109	Arkansas City.	Cowley.	Limestone.	150	4.07	14.9	2.7	0.0	3	56
1111	do.	do.	do.	153	5.18	(1)	(1)	3.1	3	29
5248	Moline.	Elkford.	do.	159	1.62	7.2	5.6	10.8	5	23
1765	Oswego.	Labette.	do.	168	0.73	9.2	4.3	13.5	6	40
4127	(2)	Leavenworth.	Quartzite.	165	0.33	2.2	18.2	19.3	25	18
4186	Fort Leavenworth.	do.	Argillaceous limestone.	162	2.38	4.6	8.7	15.1	7	37
4187	do.	do.	Limestone.	165	1.20	4.0	10.0	15.6	11	29
2689	Blue Rapids Township.	Marshall.	do.	156	3.22	6.3	6.4	9.0	4	31
2690	do.	do.	do.	150	5.65	8.6	4.2	15.0	3	34
2691	Stockdale.	do.	do.	150	6.18	9.6	4.6	11.7	3	35
9267	Fredonia.	Wilson.	Argillaceous dolomite.	168	1.01	9.0	4.6	12.8	4	12

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

LOUISIANA.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
7695	(¹)		Limonite ore.....	Pounds.	Pounds.			(²)		75
5634A	Shreveport.....	Bossier Parish.....	Ferruginous sandstone.....	209	4.24	18.2	2.2	4.8	4	49
5634B	do.....	Caddo Parish.....	do.....	159	3.31	13.8	2.9	13.8	8	36
4316	Near De Lode Bluffs.....	Rapides Parish.....	Quartzite.....	168	3.06	19.6	2.0	15.3	8	25
6664	Many.....	Sabine Parish.....	Siliceous limestone.....	147	1.53	3.8	10.5	14.7	10	369
7024	Kentwood.....	Tangipahoa Parish.....	Ferruginous limestone.....	165	2.20	4.7	8.6	12.1	2	76
3736	Winfield.....	Winn Parish.....	Marble.....	153	3.65	30.3	1.3	14.7	5	38
				168	.28	7.2	5.6	10.7		

MAINE.

6467	Rumford Junction.....	Androscoggin.....	Biotite gneiss.....	168	0.45	5.7	7.0	17.8	7	82
6469	do.....	do.....	do.....	172	.49	5.4	7.4	(³)	(²)	41
2223	Standish.....	Cumberland.....	Biotite schist.....	172	.39	4.0	10.0	10.8	7	26
5766	Westbrook.....	do.....	do.....	172	.32	4.3	9.3	17.0	7	75
2235	Portland.....	do.....	Quartzite schist.....	172	.27	2.6	15.4	17.7	14	48
7572	Freeport.....	do.....	Micaceous quartzite.....	168	.32	6.0	6.7	18.1	7	36
7310	Portland.....	do.....	Amphibolite quartzite.....	172	.27	2.5	16.0	18.4	10	29
2310	Harpswell Center (1 mile south of).....	do.....	Diabase.....	187	.57	2.1	18.9	16.6	30	82
7552	Portland.....	do.....	Altered diabase.....	178	.70	3.4	16.6	16.8	25	124
6900	Yarmouth.....	do.....	Altered diabase porphyry.....	184	.03	2.0	13.3	19.0	24	58
7577	Falmouth.....	do.....	Diabase.....	187	.27	2.5	13.7	18.4	11	11
7649	Cumberland.....	do.....	Altered diabase.....	184	.45	(²)	(²)	17.8	12	25
2958	Portland.....	do.....	Gneiss.....	165	.65	3.5	11.5	16.7	11	13
3493	Rocky Hill.....	do.....	Granite gneiss.....	165	.36	3.5	11.5	17.3	12	48
4491	Portland.....	do.....	Gneiss.....	172	.63	4.0	10.1	16.7	10	40
4557	Yarmouth.....	do.....	Biotite gneiss.....	168	.17	4.2	6.5	17.7	7	22
7573	Freeport.....	do.....	do.....	172	.64	0.9	8.7	18.0	7	20
7574	Brunswick.....	do.....	do.....	172	.31	10.7	3.7	16.2	5	27
8061	Cumberland.....	do.....	do.....	172	.93	4.1	8.1	18.9	7	5
7506	Falmouth.....	do.....	Granite.....	162	.41	4.9	12.9	17.7	14	24
7507	do.....	do.....	Biotite granite.....	172	.29	3.1	9.3	18.7	9	13
7508	do.....	do.....	Granite.....	162	.42	4.2	10.5	17.8	10	12
7509	Cumberland.....	do.....	Biotite granite.....	168	.37	3.8	10.3	17.8	14	16
7510	Freeport.....	do.....	Granite.....	165	.31	3.4	8.9	18.6	8	21
7571	do.....	do.....	do.....	162	.29	4.5	8.9	18.8		

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

MARYLAND.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
4954	Cumberland	Allegheny	Limestone	Pounds. 168	Pounds. 0.15	4.0	10.0	16.5	12	37
5611	Mount Savage Junction	do.	Siliceous limestone	165	1.13	3.0	13.3	17.5	23	38
427	Cumberland	do.	Sandstone	123	9.43	8.2	4.9	(1)	(1)	(1)
428	do.	do.	Calcareous shale	168	1.90	16.2	2.5	(1)	(1)	(1)
430	do.	do.	Silica rock	168	1.70	13.4	3.0	(1)	(1)	(1)
1328	Sparks Station	Baltimore	Biotite gneiss	178	.25	4.0	10.0	17.7	11	18
1339	do.	do.	Granite gneiss	178	.32	2.9	13.7	18.2	16	52
2206	Ruxton	do.	Biotite gneiss	175	.45	3.8	10.5	16.3	8	52
873	Powhatan	do.	Diabase	(1)	(1)	2.2	18.5	(1)	12	7
1613	do.	do.	Augite diorite	196	.31	3.6	11.2	18.3	23	52
5976	Loveley	do.	do.	190	.19	2.4	16.5	17.8	10	15
2544	do.	do.	Hornblende schist	196	.27	1.9	21.5	17.3	15	15
2952	do.	do.	do.	190	.38	3.6	11.2	18.1	15	10
3052	Big Gun Powder	do.	Dolomitic marble	180	.20	6.3	6.3	11.0	16	19
6867	Texas	do.	Siliceous marble	178	.26	27.0	2.1	7.5	5	15
6868	do.	do.	do.	168	.06	18.8	2.1	4.5	3	69
6869	do.	do.	Altered peridotite	172	.06	10.5	3.8	12.3	2	18
3187	Whitehall (near)	do.	Granite	165	.73	3.0	13.2	15.0	12	91
4104	Granite	do.	do.	168	.46	2.4	16.9	18.5	10	16
4105	Woodstock	do.	do.	165	.32	4.5	8.9	18.7	10	13
8351	Granite	do.	Biotite granite	168	.33	3.0	13.3	18.7	9	14
5818	Ashland	do.	Blast-furnace slag	178	.56	4.0	10.0	(1)	(1)	22
830	Groves Quarry	do.	Siliceous limestone	172	.09	2.6	15.6	(1)	(1)	31
3459	Port Deposit	Caroline	Granite gneiss	168	.17	2.0	20.2	18.7	10	13
6971	do.	Cecil	Quartzite	178	.30	20.4	18.9	24	24	29
8420	do.	do.	Hornblende schist	171	.26	2.2	18.2	19.2	9	29
(2)	do.	do.	Dolomite	178	.25	4.5	8.9	(1)	(1)	46
5688	Frederick	do.	do.	175	.20	3.1	12.8	16.3	15	46
439	do.	do.	Argillaceous limestone	162	.19	.9	6.8	(1)	(1)	60
1314	Frederick (near)	do.	Limestone	172	.19	2.8	14.1	14.6	12	(1)
487	Frederick	do.	do.	168	.13	6.0	6.6	(1)	(1)	56
2473	Washington Junction	do.	do.	175	.21	3.9	10.2	(1)	(1)	53
3836	Frederick	do.	do.	168	.33	3.3	12.1	(1)	(1)	53
4884	do.	do.	do.	175	.08	4.1	9.9	(1)	(1)	10
2474	Washington Junction	do.	Diabase	187	.40	1.1	36.4	10.7	16	10
2227	do.	do.	Limestone	188	.43	3.7	17	18.8	21	17
3134	Bloomington	Garrett	Feldspathic sandstone	162	.74	10.9	15.3	4	4	96
5761	Sue Quarry	do.	Calcareous sandstone	165	.62	3.7	10.8	15.8	11	58
7291	Conowingo	Cecil	Hypersthene diabase	187	.49	2.8	14.3	15.4	8	41

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916*—Contd.

MARYLAND—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				Pounds.	Pounds.					
5529	Seneca.	Montgomery	Mica schist.	168	1.67	12.2	3.3	(1)	(1)	76
2454	Washington Grove.	do.	Quartz.	165	.08	14.3	2.7	(1)	(1)	2
5723	Germanstown.	do.	do.	165	.03	7.3	5.5	(1)	(1)	0
6953	Rockville (near).	do.	do.	163	.20	10.9	3.7	(1)	(1)	1
2944	Seneca.	do.	Sandstone.	168	1.03	8.4	8.4	11.8	11	27
2945	do.	do.	Ferruginous sandstone.	139	1.83	(1)	(1)	15.8	6	150
8136	Seneca (near).	do.	do.	136	.13	4.8	8.3	15.8	5	111
8137	do.	do.	Feldspathic sandstone.	139	.30	3.1	12.7	17.3	7	30
3389	do.	do.	Granite gneiss.	178	.37	(1)	(1)	17.7	8	21
3390	do.	do.	do.	173	.23	(1)	(1)	17.7	6	21
3391	do.	do.	Sericite gneiss.	173	1.02	(1)	(1)	17.9	13	34
3820	do.	do.	Gneiss.	168	.34	4.2	9.5	17.8	13	15
3821	do.	do.	do.	178	.19	6.3	6.4	17.8	6	30
3870	Derwood.	do.	Quartz gneiss.	178	.18	3.6	11.1	17.3	7	24
4908	Clopper.	do.	Diorite gneiss.	187	.28	5.7	7.9	17.6	12	17
5625	Rockville.	do.	Altered gneiss.	190	.38	5.5	7.2	16.8	12	17
6957	do.	do.	Sericite gneiss.	181	.25	7.0	6.1	17.6	12	17
8622	Potomac.	do.	Chloritic gneiss.	175	.16	(1)	(1)	16.9	7	30
6009	Gethersburg.	do.	Chlorite sericite gneiss.	168	.50	5.7	7.0	18.7	4	18
3217	Laurel.	Prince George.	Feldspathic quartzite.	172	.04	5.7	31.7	18.1	13	15
7921	Easton.	do.	Hornblende schist.	190	.26	3.9	10.6	18.3	(1)	(1)
8092	do.	do.	Dolomitic marble.	168	.22	2.7	14.9	18.8	7	13
7505	Hancock.	do.	Hornblende granite gneiss.	172	.62	2.7	14.7	18.2	18	26
5826	Hagerstown.	do.	Ferruginous sandstone.	168	.18	5.2	7.7	16.7	13	29
8445	Security.	do.	Limestone.	168	.08	5.7	7.0	16.7	6	35
8446	do.	do.	do.	168	.43	6.0	6.7	15.9	4	45

MASSACHUSETTS.

10	Lenox.	Berkshire	Mica schist.	178	(1)	5.0	8.0	(1)	(1)	(1)
41	Lee.	do.	Schist.	(1)	(1)	3.3	12.2	(1)	(1)	(1)
69	Pittsfield.	do.	Mica schist.	172	(1)	4.1	9.8	(1)	(1)	8
2928	Lenox.	do.	Sericite schist.	187	0.19	4.1	9.8	16.8	(1)	(1)
47	Great Barrington.	do.	Limestone.	(1)	(1)	4.2	9.5	(1)	(1)	(1)
102	Pittsfield.	do.	do.	175	(1)	4.3	9.4	(1)	(1)	(1)

298	North Adams	do.	do.	do.	do.	4.7	8.5	(1)	(1)	21	(1)	(1)	(1)	23
51	Lee	do.	Gneiss.	do.	do.	3.5	11.4	(1)	(1)	39	(1)	(1)	(1)	26
8287	North Adams	do.	Biotite gneiss.	do.	do.	7.7	5.2	(1)	(1)	10	(1)	(1)	(1)	24
80	Great Barrington.	do.	Quartzite.	do.	do.	2.7	14.6	(1)	(1)	18	(1)	(1)	(1)	16
104	Lee	do.	do.	do.	do.	3.4	11.7	(1)	(1)	10	(1)	(1)	(1)	16
121	do.	do.	do.	do.	do.	3.4	11.7	(1)	(1)	10	(1)	(1)	(1)	13
8440	North Adams	do.	do.	do.	do.	3.5	11.4	(1)	(1)	10	(1)	(1)	(1)	14
119	Florida.	do.	Styrie.	do.	do.	19.8	2.0	(1)	(1)	9	(1)	(1)	(1)	14
101	Lee	do.	Marble.	do.	do.	14.0	2.9	(1)	(1)	10	(1)	(1)	(1)	14
6118	Great Barrington.	do.	do.	do.	do.	17.8	7.4	(1)	(1)	10	(1)	(1)	(1)	14
326	Lanesborough.	do.	Blast furnace slag.	do.	do.	10.6	3.8	(1)	(1)	14	(1)	(1)	(1)	35
1008	Becket.	do.	Gneissoid granite.	do.	do.	169	.04	(1)	(1)	14	(1)	(1)	(1)	35
77	North Dartmouth.	do.	Granite.	do.	do.	168	.23	(1)	(1)	14	(1)	(1)	(1)	32
81	North Westport.	do.	Hornblende granite.	do.	do.	168	1.59	(1)	(1)	8	(1)	(1)	(1)	32
445	Taunton.	do.	Granite.	do.	do.	168	.62	(1)	(1)	8	(1)	(1)	(1)	32
9485	New Bedford.	do.	Chlorite gneiss.	do.	do.	181		(1)	(1)	15	(1)	(1)	(1)	39
1	Essex.	do.	Augite diorite.	do.	do.	165		(1)	(1)	16	(1)	(1)	(1)	39
35	Newberry.	do.	Quartz diorite.	do.	do.	172		(1)	(1)	15	(1)	(1)	(1)	112
117	Beverly.	do.	Diorite.	do.	do.	184	.33	(1)	(1)	15	(1)	(1)	(1)	67
611	Salen.	do.	Augite diorite.	do.	do.	187	.18	(1)	(1)	16	(1)	(1)	(1)	39
351	Peabody.	do.	do.	do.	do.	168	.35	(1)	(1)	15	(1)	(1)	(1)	39
1945	Beverly.	do.	Diorite.	do.	do.	165		(1)	(1)	15	(1)	(1)	(1)	39
15	Saugus.	do.	Hornblende granite.	do.	do.	172		(1)	(1)	15	(1)	(1)	(1)	39
34	Rockport.	do.	do.	do.	do.	184		(1)	(1)	15	(1)	(1)	(1)	39
62	Beverly.	do.	do.	do.	do.	165		(1)	(1)	15	(1)	(1)	(1)	39
74	do.	do.	Granite.	do.	do.	172		(1)	(1)	15	(1)	(1)	(1)	39
89	do.	do.	Hornblende granite.	do.	do.	184		(1)	(1)	15	(1)	(1)	(1)	39
116	Ipswich.	do.	do.	do.	do.	162		(1)	(1)	15	(1)	(1)	(1)	39
1191	Lawrence.	do.	Gneissoid granite.	do.	do.	168	.72	(1)	(1)	21	(1)	(1)	(1)	23
1550	Beverly.	do.	Hornblende granite.	do.	do.	147	.39	(1)	(1)	21	(1)	(1)	(1)	23
1759	Gloucester.	do.	Granite.	do.	do.	165	2.77	(1)	(1)	21	(1)	(1)	(1)	23
4012	Peabody.	do.	Hornblende granite.	do.	do.	165	.05	(1)	(1)	21	(1)	(1)	(1)	23
8890	Rockport.	do.	Biotite granite.	do.	do.	163	.22	(1)	(1)	21	(1)	(1)	(1)	23
6891	do.	do.	do.	do.	do.	163	.17	(1)	(1)	21	(1)	(1)	(1)	23
6892	do.	do.	do.	do.	do.	165	.15	(1)	(1)	21	(1)	(1)	(1)	23
6893	do.	do.	do.	do.	do.	165	.24	(1)	(1)	21	(1)	(1)	(1)	23
6894	do.	do.	do.	do.	do.	165	.29	(1)	(1)	21	(1)	(1)	(1)	23
16	Lynn.	do.	Diabase.	do.	do.	190		(1)	(1)	21	(1)	(1)	(1)	23
21	do.	do.	do.	do.	do.	190		(1)	(1)	21	(1)	(1)	(1)	23</

1 Test not made.

² Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

MASSACHUSETTS—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Percent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				Pounds.	Pounds.					
329	Merrimac.	Essex	Diabase	(1)	(1)	3.1	12.9	(1)	(1)	(1)
1190	Lawrence.	do.	do.	184	.57	2.0	20.4	17.9	24	500
5825	Cliftondale.	do.	Altered diabase.	181	.32	2.7	14.7	17.6	21	43
24	Lynn.	do.	Felsite.	165	(1)	3.3	12.3	(1)	(1)	(1)
97	Rowley.	do.	do.	165	(1)	3.3	12.3	(1)	(1)	(1)
26	Gloucester.	do.	Hornblende granite.	165	(1)	3.6	11.0	(1)	(1)	(1)
30	do.	do.	Angite syenite.	172	(1)	3.2	12.6	(1)	(1)	(1)
2297	Swampscott.	do.	do.	190	.28	3.1	12.7	17.8	14	62
2648	Salem.	do.	Altered syenite.	187	.23	2.2	18.5	17.3	8	375
33	Salisbury.	do.	Campionite.	175	(1)	2.4	16.8	(1)	(1)	(1)
65	Lawrence.	do.	Siliceous limestone.	172	(1)	2.3	17.2	(1)	(1)	(1)
222	do.	do.	Limestone.	(1)	(1)	2.1	19.0	(1)	(1)	(1)
181	Methuen.	do.	Quartzite.	(1)	(1)	2.9	14.0	(1)	(1)	(1)
226	do.	do.	do.	(1)	(1)	2.1	18.7	(1)	(1)	(1)
1192	Lawrence.	do.	Granite gneiss.	165	.38	(1)	(1)	19.0	12	14
1375	Peabody.	do.	Altered gabbro.	184	.23	2.9	13.7	(1)	(1)	28
3543	Haverhill.	do.	Hornblende mica schist.	172	.51	3.2	12.3	18.4	17	26
39	Orange.	Franklin	Hornblende granite.	(1)	(1)	4.1	9.8	(1)	(1)	(1)
50	Buckland.	do.	Hornblende gneiss.	(1)	(1)	5.0	7.9	(1)	(1)	(1)
52	do.	do.	do.	(1)	(1)	3.4	11.7	(1)	(1)	(1)
211	Orange.	do.	do.	(1)	(1)	3.9	10.3	(1)	(1)	(1)
76	Deerfield.	do.	do.	(1)	(1)	1.4	28.6	(1)	(1)	(1)
268	do.	do.	Diabase.	(1)	(1)	1.6	28.8	(1)	(1)	(1)
5671	Westfield.	Hampden	Altered diabase.	187	.62	2.6	24.7	17.8	28	200
12	Holy Oak.	do.	Olivine diabase.	184	(1)	2.6	15.6	(1)	(1)	(1)
66	West Springfield.	do.	Diabase.	(1)	(1)	2.0	19.7	(1)	(1)	(1)
67	Monson.	do.	do.	(1)	(1)	1.8	22.1	(1)	(1)	(1)
68	West Springfield.	do.	Olivine diabase.	187	(1)	1.8	22.1	(1)	(1)	(1)
93	do.	do.	Diabase.	(1)	(1)	1.6	25.0	(1)	(1)	(1)
517	Westfield.	do.	do.	187	.50	1.9	21.6	(1)	(1)	(1)
44	Chester.	do.	Schist.	(1)	(1)	3.3	30.7	(1)	(1)	(1)
2423	Springfield.	do.	Dolomite.	175	.98	5.4	7.4	18.2	21	28
8	North Hampton.	Hampshire	Hornblende granite.	172	(1)	3.7	10.7	(1)	(1)	(1)
6572	Ware.	do.	Altered biotite granite.	172	.24	3.1	12.8	18.3	11	24
64	Amherst.	do.	Diabase.	187	(1)	1.7	23.3	(1)	(1)	(1)
78	do.	do.	do.	(1)	(1)	2.0	20.3	(1)	(1)	(1)
2	Everett.	Middlesex.	Olivine diabase.	178	(1)	2.9	13.9	(1)	(1)	(1)

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

MASSACHUSETTS—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
1863	Hingham.....	Plymouth	Altered diabase.....	Pounds. 190	Pounds. .17	1.8	22.2	18.0	25	67
1887	do.....	do.	do.....	175	.36	2.2	18.3	18.0	19	43
3	Revere.....	Suffolk	Felsite.....	165	(1)	3.0	13.2	(1)	(1)	(1)
40	Boston.....	do.	do.....	(1)	(1)	2.5	16.1	(1)	(1)	(1)
124	Revere.....	do.	do.....	(1)	(1)	2.6	15.2	(1)	(1)	(1)
1572	Everett.....	do.	do.....	175	.95	(1)	(1)	18.6	22	21
1573	do.....	do.	Augite diorite.....	172	.91	(1)	(1)	17.7	23	27
7506	do.....	do.	Altered rhyolite.....	165	3.44	2.9	13.8	19.6	8	25
63	Revere.....	Worcester	Hornblende granite.....	187	(1)	3.2	12.6	(1)	(1)	(1)
242	Clinton.....	do.	Gneissoid granite.....	(1)	(1)	4.8	8.3	(1)	(1)	(1)
256	Fitchburg.....	do.	Granite.....	(1)	(1)	2.2	17.9	(1)	(1)	(1)
266	Worcester.....	do.	do.....	(1)	(1)	4.6	8.6	(1)	(1)	(1)
279	Clinton.....	do.	do.....	(1)	(1)	4.6	8.7	(1)	(1)	(1)
295	Fitchburg.....	do.	do.....	(1)	(1)	4.2	9.5	(1)	(1)	(1)
7522	do.....	do.	do.....	168	.28	4.4	9.1	17.2	5	28
7521	do.....	do.	do.....	165	.31	4.3	9.3	17.7	6	28
7523	do.....	do.	do.....	165	.34	3.2	12.7	17.7	6	24
8394	Worcester.....	do.	do.....	162	.72	5.6	7.1	19.0	5	61
83	Sterling.....	do.	Diabase.....	(1)	(1)	2.1	19.3	(1)	(1)	(1)
88	Athol.....	do.	Granite gneiss.....	(1)	(1)	3.2	12.5	(1)	(1)	(1)
203	Auburn.....	do.	do.....	(1)	(1)	3.2	12.5	(1)	(1)	(1)
245	Clinton.....	do.	Gneiss.....	(1)	(1)	4.5	9.0	(1)	(1)	(1)
5378	Leominster.....	do.	Granite gneiss.....	175	.36	3.6	11.0	16.4	10	40
5988	West Auburn.....	do.	Mica gneiss.....	165	.49	3.0	13.2	18.0	13	14
7711	Grafton.....	do.	Granite gneiss.....	165	.45	5.2	7.7	19.5	8	22
114	West Auburn.....	do.	Limestone.....	(1)	(1)	3.3	12.0	(1)	(1)	(1)
227	Millville.....	do.	Diorite.....	(1)	(1)	2.7	14.8	(1)	(1)	(1)
243	Clinton.....	do.	Hornblende schist.....	(1)	(1)	8.2	4.9	(1)	(1)	(1)
244	do.....	do.	Mica schist.....	(1)	(1)	4.9	8.2	(1)	(1)	(1)
411	Webster.....	do.	do.....	178	.30	6.3	6.4	(1)	(1)	(1)
5401	Leominster.....	do.	Biotite schist.....	172	.36	3.6	11.2	16.7	6	34
5379	do.....	do.	Sericite schist.....	168	.92	3.9	10.2	17.2	8	63
247	Clinton.....	do.	Felsite.....	(1)	(1)	2.5	16.1	(1)	(1)	(1)
265	Sterling.....	do.	Hornblende syenite.....	(1)	(1)	2.3	17.1	(1)	(1)	(1)
5400	Leominster.....	do.	Fieldstone.....	(1)	(1)	4.5	8.9	(1)	(1)	30

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916*—Contd.

MICHIGAN—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Percent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
2503	(1)		Quartzite.	Pounds.	Pounds.					
6470	Garfield Township	Lenawee	Limestone.	165	.24	1.9	20.8	19.5	24	4
7152	Negaunee.	Macinac	Alfred gabro.	168	.44	4.6	8.8	13.3	5	11
7153	do.	Marquette.	do.	187	.11	2.9	14.0	17.8	10	120
1153	do.	do.	do.	184	.17	2.7	15.0	17.3	12	102
2455	Marquette.	do.	Hornblende schist.	184	.14	4.7	8.5	18.0	30	194
3198	do.	do.	do.	175	.33	4.1	9.8	16.3	20	143
3199	do.	do.	do.	181	.16	2.6	15.3	16.8	18	83
1635	(1)	do.	Epidore chlorite schist.	190	.40	2.5	15.7	17.8	26	26
1636	(1)	do.	Hornblende schist.	184	.37	2.1	18.9	17.2	23	38
1637	(1)	do.	Chloritized basalt.	184	.24	2.5	15.9	17.2	22	38
1675	Negaunee.	do.	Ferruginous slate.	175	.51	4.8	8.3	15.2	10	17
1676	do.	do.	Slate.	175	.51	(2)	(2)	16.8	12	7
2456	Marquette (near).	do.	Altered diabase.	172	1.52	5.5	7.3	18.5	9	58
2645	(1)	do.	do.	165	1.81	4.5	8.9	16.0	13	129
2688	Negaunee.	do.	do.	187	.17	3.4	11.7	16.8	12	151
2825	Marquette (near).	do.	do.	181	.17	4.0	10.1	17.4	10	41
3090	do.	do.	do.	184	.38	3.7	10.8	17.2	19	43
5030	do.	do.	do.	187	.14	1.5	26.7	18.3	33	37
2826	do.	do.	do.	185	.18	2.6	15.4	16.7	20	31
1629	Ida.	Monroe.	Quartzite.	165	.07	3.3	12.1	(2)	(2)	4
3834	Monroe.	do.	Dolomite.	162	3.46	6.0	6.6	13.3	7	34
3835	do.	do.	do.	165	2.80	4.0	10.1	14.4	6	20
4955	Bedford.	do.	do.	165	3.28	4.5	8.8	14.8	5	24
6085	Kalamazoo.	do.	do.	175	1.29	4.1	9.8	14.9	10	18
5003	Ida.	do.	Dolomite.	175	1.54	6.4	6.3	5.7	13	11
9222	Roger's City.	Presque Isle.	Calcareous sandstone.	165	2.26	6.2	6.5	18.4	13	16
9593	Caliste.	do.	Limestone.	162	1.86	5.4	7.4	(2)	(2)	28
2806	Manistique.	do.	do.	165	.74	5.6	7.1	14.3	5	15
2807	do.	Schoolcraft.	do.	168	.32	4.5	8.8	15.8	6	25
2808	do.	do.	do.	172	.27	4.2	9.4	14.3	6	26
2808	do.	do.	do.	175	1.00	2.7	14.9	16.7	12	27
2874	do.	do.	Slag.	181	1.81	23.4	1.7	18.0	7	3
3254	Limekiln crossing.	Wayne.	Dolomite.	168	3.77	4.8	8.3	12.6	4	14
8301	(1)	do.	do.	162	.23	4.9	8.2	14.8	4	18
3255	Detroit.	do.	Limestone.	168	.87	5.4	7.4	13.3	9	17
4821	do.	do.	Blast furnace slag.	159	1.01	9.3	4.3	11.3	2	88

MINNESOTA.

9532	Mankato.....	Blue Earth.....	Argillaceous-dolomite.....	159	3.22	4.7	8.5	16.7	14	51
1010	Carlton.....	do.....	Slate.....	175	.67	6.0	6.7	11.2	5	43
2442	do.....	do.....	do.....	172	.53	2.8	14.3	12.7	10	75
3764	Mantorville.....	Dodge.....	Dolomite.....	150	8.24	11.5	3.5	2.0	3	41
1170	Courtland.....	Nicollet.....	Quartzite.....	165	.39	1.6	24.5	19.7	22	42
2340	do.....	do.....	do.....	165	.15	2.1	19.2	12	13	11
2410	Pipestone.....	Pipestone.....	Ferruginous sandstone.....	172	.40	4.6	8.8	14.5	16	16
7954	Sandstone.....	Pine.....	do.....	156	1.40	11.6	3.3	15.2	4	6
8943	do.....	do.....	Sandstone.....	156	1.23	13.8	2.9	14.8	4	55
2426	Redwood Falls.....	Redwood.....	Granite gneiss.....	165	.28	2.4	16.8	19.0	16	17
1241	do.....	do.....	Weathered granite.....	134	(²)	15.2	2.6	(²)	2	255
1241	St. Cloud.....	Sherburne.....	Granite-dolite.....	168	.12	12	(²)	18.0	19	9
807	Duluth.....	St. Louis.....	Olivine gabbro.....	172	.12	4.7	8.6	17.4	10	42
5301	do.....	do.....	Altered gabbro.....	172	.50	5.2	7.8	16.8	8	134
2909	Minnesota City.....	do.....	Dolomite.....	168	1.74	5.0	8.0	13.3	5	42
5524	Stockton.....	Winona.....	Argillaceous dolomite.....	165	2.97	7.9	3.1	5.6	5	43

MISSISSIPPI.

2590	Kosciusko.....	Attala.....	Sandstone.....	162	0.90	6.3	6.3	19.2	14	5
5890	Houston.....	Chickasaw.....	Argillaceous limestone.....	150	6.28	12.2	3.3	6.7	5	49
6812	Woodland.....	do.....	Ferruginous sandstone.....	162	4.91	23.7	1.7	(²)	(²)	12
4532	Stonington.....	Jefferson.....	Sandstone, ferruginous.....	131	11.60	31.8	1.3	(²)	(²)	(²)
8240	(¹).....	Lauderdale.....	Opaline sandstone.....	139	.60	14.9	2.7	18.5	5	127
8241	(¹).....	do.....	Sandstone.....	153	1.91	6.2	6.5	19.3	10	9
1514	Columbus.....	Lowndes.....	Limestone.....	159	3.46	4.2	9.5	7.4	6	41
6080	do.....	do.....	Argillaceous limestone.....	162	2.40	5.3	7.6	10.0	6	22
5897	Holly Springs.....	Marshall.....	Ferruginous sandstone.....	181	1.72	28.1	1.4	15.4	3	27
6607	District No. 1.....	Neshoba.....	Argillaceous sandstone.....	119	14.00	10.1	4.0	11.0	5	304
5871	Macon.....	Noxubee.....	Limestone.....	165	1.57	4.5	8.9	13.7	10	21

MISSOURI.

1775	Kirkville.....	Adair.....	Limestone.....	165	1.25	4.9	8.1	16.5	8	31
1289	Columbia.....	Boone.....	do.....	165	.85	8.8	4.6	0	4	69
1290	do.....	do.....	do.....	162	7.7	6.6	6.1	8.5	3	36
6375	Rocheport.....	do.....	do.....	165	1.31	9.3	4.3	12.3	3	50
4376	Portland.....	Callaway.....	Argillaceous dolomite.....	153	3.78	8.7	4.6	(²)	(²)	50
4398	Cape Girardeau.....	Cape Girardeau.....	Limestone.....	168	.49	3.7	10.8	15.8	9	42
6377	Sweeney.....	Cooper.....	Argillaceous limestone.....	165	2.67	4.8	8.3	13.5	8	46
1027	Springfield.....	Greene.....	Chert.....	165	.94	5.4	7.5	(²)	(²)	106

² Test not made.¹ Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

MISSOURI—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
6472	Kansas City.....	Jackson.....	Limestone.....	Pounds. 165	Pounds. 1.82	4.8	8.3	13.4	6	45
6473	do.....	do.....	do.....	162	1.82	6.3	6.3	13.2	4	25
7096	(1)	do.....	do.....	168	.67	7.2	5.6	14.1	2	16
7095	Independence.....	do.....	do.....	163	.90	5.3	7.5	12.0	2	67
7097	do.....	do.....	do.....	130	4.66	19.4	2.1	4.5	3	33
1862	Carthage.....	Jasper.....	do.....	168	.22	6.0	6.3	7.3	5	67
6045	do.....	do.....	do.....	165	.83	6.4	6.3	7.7	5	(2)
3203	Webb City.....	do.....	Chert.....	162	.58	4.5	8.9	(2)	(2)	35
1521	Edina.....	Knox.....	Limestone.....	165	.96	7.1	5.6	6.1	5	94
5180	Lexington.....	Lafayette.....	do.....	163	1.38	4.5	8.8	13.7	6	27
1511	Macon.....	do.....	do.....	168	1.35	3.4	11.7	10.6	14	37
1513	do.....	do.....	do.....	168	1.07	3.9	10.4	16.1	14	35
1080	Mine La Motte.....	do.....	do.....	175	.52	4.0	10.1	15.5	10	35
1016	Neosho.....	Madison.....	do.....	(2)	(2)	4.6	8.8	(2)	(2)	(2)
1125	do.....	Newton.....	Chert.....	125	11.10	6.9	5.8	19.6	21	38
1634	Vider's post office.....	St. Louis.....	Limestone.....	165	1.03	3.9	10.4	14.7	8	31
1081	St. Louis.....	do.....	do.....	168	.75	3.8	10.4	14.6	9	55
1596	do.....	do.....	do.....	168	.60	5.6	7.2	12.8	6	30
7284	Minecke.....	do.....	do.....	168	.60	6.4	6.3	10.2	4	34
8221	St. Louis.....	do.....	do.....	168	1.33	3.9	10.3	(2)	(2)	45
8216	do.....	do.....	do.....	168	.73	3.7	10.8	(2)	(2)	40
8217	do.....	do.....	do.....	168	.64	3.8	10.5	14.3	6	53
8215	do.....	do.....	do.....	168	.75	4.9	8.2	16.7	7	62
2114	Sedalia.....	Pettis.....	do.....	165	.57	7.6	9.7	5.3	5	46
2115	do.....	do.....	do.....	165	2.14	4.1	9.7	6.9	4	34

MONTANA.

2157	Anaconda.....	Deer Lodge.....	Limestone.....	165	0.74	7.5	5.3	13.1	3	76
1649	Bozeman.....	Gallatin.....	Sandstone.....	156	2.13	3.8	10.5	18.7	15	4
1651	do.....	do.....	Calcareous sandstone.....	162	1.77	3.4	11.6	16.5	15	200
8650	Billings.....	Yellowstone.....	do.....	165	1.05	3.7	10.8	17.3	10	81

NEBRASKA.

2840	Cedar Creek	Cass	Limestone	105	1.19	5.4	7.4	14.9	6	50
2841	do	do	do	165	.85	5.9	6.8	13.5	6	41
2842	do	do	do	165	1.61	4.7	8.6	13.2	6	59
2843	Nehawka	do	do	165	.83	4.9	30	14.7	5	30
2844	do	do	do	139	2.43	5.4	7.4	11.4	6	145
360	Blue Springs	Gage	Flint	159	1.33	5.8	6.9	(2)	(2)	(2)
3091	Wymore	do	Dolomitic chert	156	3.98	11.8	3.4	(2)	(2)	16
1361	Johnson Town	Nemaha	Limestone	150	5.30	3.7	10.7	16.2	5	32
1362	do	do	do	153	4.40	10.1	4.0	4.0	4	29
1509	Auburn	do	do	159	3.12	4.4	159	6.2	7	84
1510	do	do	do	153	4.38	5.1	7.8	11.0	7	111

NEW HAMPSHIRE.

370	Hanover	Very coarse granite	165	0.21	3.2	12.6	(2)
371	do	Hornblende schist.	193	.22	3.3	12.3	(2)
372	do	do	190	.38	4.0	9.9	(2)
373	Lebanon	do	168	.47	5.9	6.7	(2)
2102	do	Biotite schist	165	.80	2.3	17.2	18.2
2103	do	Quartzite schist	187	.71	1.8	21.7	18.0
2104	do	Porphyritic diorite	134	.87	2.3	16.3	17.2
2105	do	Diorite	181	.39	2.2	18.0	16.9
2185	do	Altered diabase	165	.15	4.0	10.0	(2)
2187	do	do	165	.15	5.9	6.7	(2)
4050	Hillsborough	Sandstone	168	.71	29	29	6
5545	do	Biotite gneiss	168	.55	10.3	3.9	62
5751	Merrimack	Biotite schist	165	.19	2.8	14.3	39
5750	do	do	165	.26	3.5	11.4	23
5752	do	Biotite granite	165	.59	3.6	11.1	9
9009	do	do	165	.31	4.6	8.8	15
8872	do	Granite	165	.47	3.6	11.0	(2)
2153	do	do	165	(2)	3.8	18.5	34
8870	Concord	do	165	.63	3.9	10.5	10
9036	do	do	165	.52	4.1	17.7	8
9037	do	do	165	.43	4.0	9.7	7
9031	do	do	165	.43	4.0	10.0	10
2362	Rockingham	Altered rhyolite	172	.14	2.7	14.8	7
1779	Farmington	Granite	165	.29	3.7	10.8	11
						17.3	12
							19
							25
							19
							500+

Exact locality not known.

² Test not made.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Cont'd.*

NEW JERSEY.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Comenting value.
260	Great Notch.....	Essex.....	Diabase.....	Pounds. (1)	Pounds. (1)	1.8	21.8	(1)	(1)	(1)
261	do.....	do.....	do.....	(1)	(1)	2.2	18.6	(1)	(1)	(1)
986	Montclair.....	do.....	Basalt.....	181	0.95	1.9	21.3	18.4	24	125
987	do.....	do.....	do.....	187	.61	1.8	21.7	17.6	35	283
988	do.....	do.....	do.....	187	.30	1.7	24.1	18.8	29	45
1718	Milburn.....	do.....	do.....	184	.10	2.0	20.0	18.0	21	120
1721	West Orange.....	do.....	Altered basalt.....	184	.10	1.8	22.0	18.5	21	113
1727	Verona.....	do.....	Basalt.....	181	.50	2.3	17.7	17.3	17	500+
1733	West Orange.....	do.....	Altered basalt.....	187	.10	1.8	22.7	17.8	24	238
1754	do.....	do.....	Basalt.....	187	.10	1.4	27.8	17.3	28	60
1755	do.....	do.....	do.....	184	.36	2.3	17.7	18.3	28	77
1755	Guttenberg.....	Hudson.....	do.....	(1)	(1)	1.3	30.4	(1)	(1)	(1)
1751	Secaucus.....	do.....	Gabbroitic diabase.....	184	.12	2.8	14.2	18.3	27	92
1756	do.....	do.....	do.....	187	.18	2.1	19.0	18.3	18	88
1773	Jersey City.....	do.....	Olivine diabase.....	196	.13	2.5	16.1	18.3	19	31
251	Byram Station.....	Hunterdon.....	Basalt.....	(1)	(1)	1.5	26.9	(1)	(1)	(1)
253	Lambertville.....	do.....	Hornblende granite.....	(1)	(1)	2.8	14.2	(1)	(1)	(1)
387	do.....	do.....	Altered gabbro.....	184	.14	2.8	14.3	(1)	(1)	(1)
903	do.....	do.....	Gabbroitic diabase.....	(1)	(1)	(1)	(1)	17.1	23	(1)
2065	Whitehouse.....	do.....	Altered diabase.....	181	1.08	1.8	21.7	17.5	18	385
2786	Whitehouse.....	do.....	do.....	184	.47	2.6	15.6	18.3	27	45
2838	do.....	do.....	Dolomite.....	178	.39	3.7	10.9	17.0	10	43
2842	do.....	do.....	do.....	178	.37	3.3	12.2	16.3	13	15
1015	do.....	do.....	do.....	177	.15	3.7	10.8	16.9	13	43
4026	Milford (near).....	do.....	Calcareous sandstone.....	168	.52	(1)	17.6	17.6	17	25
5233	Clinton.....	do.....	Siliceous limestone.....	175	.25	3.0	13.5	17.6	25	21
5548	Middle Valley.....	do.....	Hornblende gneiss.....	187	.17	2.8	14.3	18.7	26	34
5946	High Bridge.....	do.....	Augite diorite.....	190	.95	3.9	10.2	18.5	16	38
6035	Flemington (near).....	do.....	Siliceous slate.....	162	.32	(1)	(1)	17.3	27	52
286	Hopewell.....	Mercer.....	Diabase.....	(1)	(1)	2.5	16.3	(1)	(1)	(1)
5446	Pennington.....	do.....	Altered diabase.....	184	.26	3.8	10.5	17.7	17	42
6008	do.....	do.....	Gabbroitic diabase.....	187	.05	2.4	16.4	18.5	21	(1)
249	Bergen Hill.....	Middlesex.....	Gabbro.....	(1)	(1)	2.7	15.0	(1)	(1)	(1)
250	Wilmington.....	Morris.....	Basalt.....	(1)	(1)	2.0	19.6	(1)	(1)	(1)
303	Middle Valley.....	do.....	Diabase.....	(1)	(1)	1.5	26.3	(1)	(1)	(1)
405	do.....	do.....	do.....	187	.09	1.7	23.8	(1)	(1)	(1)
1708	Millington.....	do.....	do.....	187	.61	2.7	14.9	17.7	18	500+
2902	Middle Valley.....	do.....	Altered diabase.....	187	.19	2.5	15.7	18.7	32	69
2280	Libertina.....	do.....	Quartz syenite.....	165	.21	3.2	12.6	18.8	12	16

Locality	Sample No.	Rock	Grain Size	Color	Texture	Mineralogy	Chemical Analysis	Notes
Montville	5571	do.	.....	.....	.....	Hyporthene granite	175	27
Warton	7194	do.	.....	.....	.....	Flint-lumace slag	131	4.47
Warton	478	Passaic	.....	.....	.....	Peridotite	200	.33
Montclair Heights	1713	do.	.....	.....	.....	Basalt	184	.28
Paterson	1716	do.	.....	.....	.....	do.	181	.39
Albion Place	1717	do.	.....	.....	.....	do.	184	.59
Mountain View	1730	do.	.....	.....	.....	do.	184	.85
Paterson	1731	do.	.....	.....	.....	do.	184	.59
Rocky Hill	248	Somerset	.....	.....	.....	Gabbro	(1)	(1)
Boundbrook	252	do.	.....	.....	.....	Basalt	187	.12
Chimney Rock	357	do.	.....	.....	.....	do.	147	6.32
Somerville	637	do.	.....	.....	.....	Basalt-tuff	150	5.69
do.	669	do.	.....	.....	.....	do.	181	1.81
do.	669	do.	.....	.....	.....	do.	187	.41
North Plainfield	2995	do.	.....	.....	.....	Diabase	(1)	(1)
Chimney Rock	284	do.	.....	.....	.....	do.	(1)	(1)
Warrenville	1706	do.	.....	.....	.....	do.	187	.33
Bernardsville	1719	do.	.....	.....	.....	Altered diabase	178	.24
Belmeade (near)	4952	do.	.....	.....	.....	do.	187	.57
Rocky Hill	285	do.	.....	.....	.....	Diabase	187	.15
Bernardsville	287	do.	.....	.....	.....	Cratic gabbro	(1)	(1)
do.	2205	do.	.....	.....	.....	Limestone	(1)	(1)
Hamberg	3504	Sussex	.....	.....	.....	Dolomite	178	.64
New Providence	350	Union	.....	.....	.....	Altered syenite	184	.12
do.	6585	do.	.....	.....	.....	Diabase	187	.39
Springfield	912	do.	.....	.....	.....	Altered diabase	184	.45
Summit	1707	do.	.....	.....	.....	Basalt	181	1.15
Springfield	6595	do.	.....	.....	.....	do.	184	.32
Summit	6586	do.	.....	.....	.....	do.	181	.97
Washington	3145	Warren	.....	.....	.....	Altered diabase	184	1.00
do.	7436	(2)	.....	.....	.....	Siliceous dolomite	178	.14
do.	7436	(2)	.....	.....	.....	Diabase	187	.45

NEW YORK.

1193	Albany.....	Albany.....	168	0.68	2.9	13.8	17.1	20	39
1480	South Bethlehem.....	Limestone	168	1.58	4.8	8.4	16.1	10	10
1493	do.....	Limestone	165	1.58	3.2	12.7	14.7	10	36
1673	Guthrie.....	Siliceous limestone	168	1.53	4.7	8.6	18.2	9	11
1675	do.....	Feldspathic quartzite	168	49	3.9	10.4	18.0	10	10
1647	do.....	Plagioclase gneiss	168	49	3.4	11.7	18.0	13	22
1648	do.....	Pyroxene gneiss	172	21	2.7	14.8	17.2	12	43
1648	do.....	Limestone	175	51	2.7	5.8	(1)	(1)	(1)
6029	Clinton Point.....	Calcareous slate	168	40	6.9	7.6	(1)	(1)	(1)
385	Hudson.....	Limestone	168	50	5.3	7.6	(1)	(1)	(1)
340	do.....	Limestone	168	50	5.3	7.6	(1)	(1)	(1)
195	Cortland.....	Dolomite	(1)	1.40	3.2	12.5	17.5	12	17
260	Poughkeepsie.....	Dolomite	178	1.40	3.2	12.5	17.5	12	17

1 Test not made.

² Exact locality not known.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916*—Contd.

NEW YORK—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
5544	Camelot.....	Dutchess.	Dolomite.....	Pounds.....	Pounds.....	2.3	17.5	16.8	23	33
6764	North Hamburg.....	do.	Slipaceous dolomite.....	175	32	2.3	17.1	17.3	20	41
8011	(1)	do.	Dolomite.....	175	24	2.3	8.0	17.6	10	317
1327	Clinton Point.....	do.	Dolomite sandstone.....	175	21	5.0	(2)	17.5	19	35
2479	Poughkeepsie.....	do.	Calcareous sandstone.....	172	44	3.7	10.9	18.0	14	31
2480	do.....	do.	do.....	172	32	4.6	8.6	15.8	14	20
2559	do.....	do.	Biotite gneiss.....	172	21	3.3	12.0	18.3	13	28
2661	do.....	do.	Quartzite.....	165	83	2.7	14.8	(3)	(2)	3
4061	Stoneco.....	do.	Dolomite marble.....	175	16	2.3	17.5	16.7	7	20
2039	Albion.....	do.	Limestone.....	168	35	5.9	16.8	18.8	7	81
5925	Buffalo.....	Erie.....	Cherty limestone.....	168	1.27	3.4	11.8	16.2	10	17
5872	(1)	do.	Cherty limestone.....	165	56	4.1	9.7	19.2	10	41
1782	Kessex.....	do.	Gabbro.....	228	74	(2)	(3)	17.0	16	6
8577	Gloversville.....	Fulton.	Biotite gneiss.....	172	19	3.7	10.8	18.0	10	28
411	Leroy.....	Genesee.	Flint.....	162	20	7.2	8.4	(3)	(2)	52
732	North Leroy.....	do.	Limestone.....	162	06	4.7	7.6	(3)	(2)	100
6755	Catskill.....	Green.	Calcareous sandstone.....	162	40	3.7	10.8	13.1	9	44
832	Little Falls.....	Herkimer.	Gneiss.....	165	23	1.9	20.7	(2)	(2)	14
1708	do.....	do.	Pyroxene gneiss.....	181	12	6.1	6.5	17.3	18	14
1709	do.....	do.	Gneiss.....	168	33	9.1	4.3	15.7	12	46
1771	do.....	do.	Pyroxene gneiss.....	162	13	7.6	3.3	14.7	17	45
1770	do.....	do.	Pyroxene quartzite.....	187	11	2.3	19.4	17.0	35	22
2512	Salisbury.....	do.	do.....	168	40	2.3	17.2	18.7	27	16
2853	Little Falls.....	do.	Crystalline dolomite.....	175	50	5.2	7.7	12.2	7	39
2650	Elmira.....	do.	Limestone.....	147	6.29	7.4	5.4	6.3	3	43
192	Round Island.....	do.	Gneiss.....	(2)	(1)	1.7	23.0	(3)	(2)	(4)
1896	Clayton.....	Jefferson.	Granite.....	165	11	2.5	16.1	18.9	14	18
7437	Alexandria Bay.....	do.	do.....	165	24	3.8	10.4	18.8	14	9
8533	do.....	do.	do.....	165	(3)	(2)	(2)	19.0	11	(2)
8902	do.....	do.	do.....	(3)	(4)	(2)	(2)	19.3	(4)	(2)
356	Brockport.....	Monroe.	Fossiliferous limestone.....	168	26	4.5	8.9	(4)	(4)	47
917	Honeye Falls.....	do.	Cherty limestone.....	168	20	3.6	11.0	(3)	(2)	29
937	do.....	do.	Nodular limestone.....	165	2.70	6.1	6.6	(3)	(2)	45
938	do.....	do.	Dolomite limestone.....	168	27	3.6	11.2	15.6	9	19
918	do.....	do.	Dolomite.....	139	3.26	4.1	9.8	15.1	16	18
1211	Amsterdam.....	do.	Limestone.....	168	44	2.2	17.9	16.5	18	82
1512	Pattersonville.....	Montgomery.	Dolomite limestone.....	175	1.27	2.6	13.2	17.5	15	43
1746	Amsterdam.....	do.	Limestone.....	168	.22	4.8	8.4	15.2	9	54

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.*

NEW YORK—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Commenting value.
6733	Haverstraw	Rockland	Diabase.....	Pounds. 184	Pounds. .82	2.3	17.4	17.8	18	66
6734	do.	do.	do.	184	.39	2.3	17.4	18.0	23	131
6735	do.	do.	Gabbroitic diabase.....	184	.56	2.6	15.6	18.1	17	309
7805	(1)	do.	Diabase.....	187	.35	2.4	16.4	18.0	18	89
8012	(1)	do.	Gabbroitic diabase.....	184	.16	4.6	8.6	18.5	14	30
6774	Tompkins Cove	do.	Siliceous dolomite.....	178	.26	4.3	9.4	16.4	9	186
6775	do.	do.	Dolomite.....	175	.44	4.9	8.2	17.7	7	70
8013	(1)	do.	Siliceous dolomite.....	175	.26	6.9	5.8	17.2	13	36
9462	Tompkins Cove	do.	do.	175	.35	4.8	8.3	16.6	13	36
4328	Massena	do.	do.	175	.41	4.3	9.4	16.5	16	22
4330	do.	St. Lawrence	do.	175	.41	3.1	13.1	16.8	20	28
1524	do.	do.	do.	175	.81	4.7	8.5	16.9	16	41
1525	Saratoga Springs	Saratoga	Hornblende gneiss.....	190	.28	2.3	17.1	17.6	18	57
1689	Stillwater	do.	Altered diabase.....	175	.42	2.8	14.1	17.5	11	20
94	Duanesburg	do.	Feldspathic sandstone.....	168	.65	2.8	10.5	(2)	(2)	(2)
188	Howes Cove	Schoenectady	Sandstone.....	(2)	(3)	4.2	9.6	(2)	(2)	(2)
1538	Cobleskill	Schoharie	Limestone.....	168	.52	4.7	8.8	13.7	7	98
382	Deerpark	do.	do.	105	1.06	4.7	8.6	(2)	(2)	(2)
1667	Smithborough	Suffolk	Sandy shale.....	162	1.06	2.7	15.0	17.3	17	15
1100	West Camp	Tioga	Feldspathic sandstone.....	168	2.06	3.0	13.2	16.9	17	61
1693	Kingston	Ulster	Limestone.....	172	.26	3.1	12.7	14.8	6	62
3832	Kingston (near)	do.	do.	168	.45	4.8	18.4	13.1	7	48
5222	Kingston	do.	Siliceous limestone.....	168	.33	4.0	17.6	16.7	8	22
5223	do.	do.	Limestone.....	168	.23	5.3	7.6	16.7	7	31
5574	Roundout	do.	do.	168	.39	5.0	7.9	16.4	10	67
2027	East Kingston	do.	Calcareous sandstone.....	168	.39	2.8	11.9	16.4	13	207
6363	Kingston	do.	Feldspathic sandstone.....	165	.94	2.8	12.8	15.0	16	23
6634	Ulster	do.	Calcareous sandstone.....	168	1.00	2.8	12.8	17.0	16	149
1257	Greenwich	do.	Calcareous sandstone.....	178	.89	5.2	13.2	13.2	10	26
6732	Smiths Basin	Washington	Siliceous dolomite.....	175	.21	2.2	18.2	16.7	19	34
983	Newark	do.	Limestone.....	173	.23	2.7	14.9	16.3	14	(2)
984	do.	Wayne	Dolomitic limestone.....	172	2.10	3.3	6.9	(2)	(2)	(2)
941	Briar Cliff Manor	do.	Limestone.....	172	.42	4.5	8.1	22.2	8	41
2100	Cortlandt	Westchester	Hornblende schist.....	190	.26	2.5	16.2	17.2	22	38
2161	do.	do.	Diorite.....	190	.56	3.0	13.2	16.7	10	106
404	Bellona	do.	do.	184	.42	3.8	10.4	16.6	8	134
1118	Toney	Yates	Limestone.....	168	.14	3.3	7.5	(2)	(2)	(2)
	do.	do.	do.	168	.22	4.3	9.2	17.3	9	40

NORTH CAROLINA.

822	Haw River.	Alamance.	Chlorite epidote schist.	0.06	3.1	13.1	18.5	34	26
7771	Burlington.	do	Altered gabbro.	184	40	11.4	16.7	9	19
825	Wadesboro.	Anson.	Diabase.	187	3.5	20.6	18.1	27	17
9226	Cramberry.	Avery.	Pentotite.	240	3.5	11.4	16.7	9	29
4991	Washington....	Beaufort.	Stuccous shell limestone.	140	33.6	7.2	17.6	5	(2)
705	Asheville (near).	Buncombe.	do.	200	15	3.7	7.1	(2)	(2)
778	Asheville....	do.	do.	193	57	11.0	(2)	(2)	(2)
627	do.	do.	Biotite schist.	172	69	11.8	(2)	(2)	(2)
628	do.	do.	Granite porphyry.	168	26	18.6	(2)	(2)	(2)
777	do.	do.	Diorite gneiss.	184	2.2	17.4	(2)	(2)	(2)
8135	do.	do.	Granite gneiss.	168	15	3.7	10.7	(2)	(2)
809	Monford (near Asheville).	do.	Biotite gneiss.	178	39	7.2	16.6	9	43
8133	Asheville.	do.	Micro granite.	165	11	2.3	(2)	(2)	13
8134	do.	do.	Granite.	165	31	14.3	18.4	11	14
4963	do.	do.	Aplitic granite.	165	2.2	18.7	18.7	7	12
535	Morgantown.	do.	Dolomite.	(2)	24	10.0	17.3	14	18
434	Concord.	Burke.	Basalt.	150	15	2.0	20.3	(2)	11
436	do.	Cabarrus.	Micro granite.	33	1.8	21.7	(2)	(2)	13
6566	do.	do.	Augite syenite.	165	29	5.7	7.0	(2)	13
513	Concord (near).	do.	do.	163	24	5.0	8.0	(2)	27
812	Hickory.	do.	Syenite.	168	28	14.4	18.5	22	35
4723	do.	Catawba.	Hornblende granite.	172	14	2.2	18.3	4	12
839	Silver City (4 miles northwest of).	do.	do.	168	24	6.9	5.8	8	20
3382	Andrews.	Chatham.	Granite gneiss.	172	24	6.3	17.9	6	61
3383	do.	Cherokee.	Chlorite epidote schist.	175	08	2.3	17.7	(2)	21
6199	Murphy.	do.	Quartzite.	165	31	4.9	19.3	15	6
7022	Regal.	do.	Marble.	172	16	6.0	6.7	3	61
6196	Murphy.	do.	do.	172	28	4.4	14.1	6	21
6197	do.	do.	do.	171	06	4.7	14.7	4	21
2576	Shelby.	do.	Mica schist.	175	43	4.1	14.0	7	12
381	New Bern.	Cleveland	Serfite schist.	162	31	6.1	16.2	10	21
3209	Thomasville (5 miles from).	Craven.	Sandstone.	157	54	3.2	12.4	6	52
7775	Newson.	do.	Biotite gneiss.	165	20	11.3	17.8	(2)	(2)
8710	do.	do.	Fossiliferous limestone.	137	1.93	34.2	18.3	32	17
2988	Durham.	do.	Altered andesite.	151	49	2.7	15.0	20	12
813	Bethania Station.	do.	Rhyolite.	165	23	2.7	14.8	33	9
1403	Winston.	do.	Altered rhyolite.	175	47	4.1	19.3	33	14
7561	Franklin.	do.	Hornblende epidote schist.	184	42	(2)	17.3	14	19
8303	Gastonia.	Forsythe.	Olivine basalt.	190	04	3.0	18.3	39	1
8882	do.	do.	Granite gneiss.	165	08	1.9	18.5	19	8
815	Greensboro.	do.	Epidote quartzite.	187	82	3.9	18.0	15	15
819	do.	do.	Granite.	165	49	5.7	17.4	5	153
819	do.	do.	Olivine diabase.	184	35	2.7	14.9	13	12
819	do.	do.	Quartzite.	175	51	2.6	18.8	(2)	(2)
819	do.	do.	Aplitic granite.	175	13	2.5	16.0	(2)	(2)
819	do.	do.	Uratitic diabase.	184	11	2.1	18.1	27	26
819	do.	do.	Diabase.	187	14	1.6	24.7	(2)	(2)

² Test not made.

Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

NORTH CAROLINA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	Franch coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
816	Jamestown.	Guilford.	Granite.	168	.15	3.4	11.7	18.0	(1)	10
817	Greensboro.	do.	do.	172	.11	2.6	15.2	(1)	(1)	11
818	do.	do.	Dolomitic sandstone.	178	.14	1.9	21.1	17.2	27	18
820	do.	do.	Gabbro.	193	.21	3.5	13.6	(1)	(1)	37
821	do.	do.	Diorite.	193	.09	2.9	12.7	(1)	(1)	21
823	do.	do.	do.	184	.06	2.5	12.4	18.4	24	20
823	do.	do.	do.	184	.06	3.2	12.4	(1)	(1)	12
810	Balfour.	Henderson.	Granite gneiss.	165	.11	3.1	12.7	18.5	10	8
2755	Hendersonville (2 miles northwest of)	do.	do.	165	.23	3.1	13.8	18.9	11	20
8376	Mooreville.	Iredell.	Biotite granite.	168	.40	3.0	13.8	17.2	8	74
6795	Sylva.	Jackson.	Biotite gneiss.	187	.28	6.1	9.2	18.1	7	24
6794	do.	do.	do.	168	.33	4.3	9.2	18.1	7	74
6793	do.	do.	Biotite schist.	184	.60	6.4	9.2	18.1	7	24
6882	do.	do.	Biotite gneiss.	172	.42	5.4	7.4	18.9	6	50
6883	do.	do.	do.	172	.28	11.0	3.4	18.9	5	32
6884	do.	do.	Dolomitic marble.	172	.27	3.3	13.1	17.2	8	24
504	Hot Springs.	Madison.	Dolomite.	181	.21	6.0	6.5	15.2	10	9
772	do.	do.	do.	178	.22	4.2	9.5	(1)	(1)	(1)
771	do.	do.	do.	178	.17	3.3	12.3	(1)	(1)	21
867	Marion.	McDowell.	Quartzite.	165	.17	2.3	17.0	17.0	19	28
2124	Old Fort (near).	do.	Biotite gneiss.	168	.20	2.3	17.0	19.0	13	20
2190	Old Fort.	do.	Sericite gneiss.	172	.10	3.8	10.6	18.3	13	50
5373	do.	do.	Gneiss.	168	.21	2.8	14.2	18.3	15	16
868	Marion.	do.	Granite gneiss.	168	.28	3.5	11.5	18.8	(1)	21
811	Charlotte.	do.	Dolomite.	175	.27	4.7	8.6	(1)	(1)	6
913	Toe Cane.	Mecklenburg.	Granite.	168	.15	2.3	17.5	18.8	31	25
840	Carthage.	Mitchell.	Micaceous eclogite.	196	.27	2.1	19.2	17.4	16	62
841	do.	Moore.	Olivine diabase.	184	.28	2.8	14.5	18.0	18	121
2768	Rocky Mountain.	Nash.	Diabase.	178	.64	2.7	15.1	18.7	18	21
7352	do.	do.	Granite.	165	.29	3.4	11.9	19.5	8	16
7353	do.	do.	Biotite granite.	165	.29	5.0	8.0	19.5	8	28
402	Wilmington.	do.	Altered granite.	162	3.00	4.9	8.2	18.8	4	(1)
834	Chapel Hill (1 1/2 miles east of).	New Hanover.	Fossiliferous limestone.	150	2.77	9.9	4.0	(1)	(1)	102
835	Hillsboro (1 mile southwest of).	Orange.	Olivine basalt.	187	.14	2.7	14.6	18.9	50	44
2465	Lynn.	do.	Altered diabase.	184	.08	1.4	29.6	17.5	8	28
2753	Tryon.	Folk.	Granite.	165	.67	4.1	9.9	16.5	10	14
5430	Rockliff.	do.	Biotite granite.	165	.36	5.8	6.9	17.8	(1)	33
514	Asheboro.	Randolph.	Granite gneiss.	172	.33	6.6	6.1	(1)	(1)	17
826	Rockingham.	Richmond.	Pelite.	168	.02	1.9	21.3	16.4	14	16
4109	Ruffin.	Rockingham.	Hypersphene gabbro.	187	.32	3.2	12.3	18.8	12	17
			Granite gneiss.	162	.47	4.3	9.2	18.8	12	16

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

OHIO.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
6093	Lima	Allen	Dolomite	Pounds.	Pounds.	4.0	10.0	15.5	11	18
9438	do	do	Argillaceous dolomite	165	2.24	2.9	13.8	15.6	7	36
3186	Jefferson	Ashtabula	Sandstone	168	2.10	2.9	13.8	15.6	7	55
977	Urbana	Champaign	Calcareous sandstone	153	2.37	10.0	4.0	9.2	20	20
978	do	do	do	159	3.60	11.4	3.5	7.3	7	32
4692	Springfield	Clark	Dolomite	159	3.90	32.8	1.2	0	5	20
4695	do	do	do	168	1.59	6.8	5.9	11.3	4	(1)
4694	Osborne	do	Dolomitic limestone	168	.60	6.7	6.0	14.0	9	(1)
5247	Melvin	Clinton	Dolomite	168	.31	6.2	6.4	9.3	4	21
6718	Leetonia	Columbiana	Blast furnace slag	162	2.11	11.8	3.4	13.8	7	400
8597	do	do	do	(1)	(1)	13.1	3.1	(1)	(1)	83
1309	Coshocton	do	Limestone	(1)	(1)	3.5	11.3	16.2	19	71
765	Chagrin Falls	Coshocton	Sandstone	168	1.10	4.4	9.8	(1)	(1)	307
9459	Cleveland	Cuyahoga	Granite	156	4.10	2.9	13.8	18.5	10	(1)
9282	do	do	do	165	.15	(1)	(1)	19.0	12	(1)
9283	do	do	do	(1)	(1)	(1)	(1)	18.8	8	(1)
9284	do	do	do	(1)	(1)	(1)	(1)	18.6	9	(1)
9285	do	do	do	(1)	(1)	(1)	(1)	18.8	11	(1)
1370	Warrenville	do	Limestone	162	1.79	7.5	5.3	12.4	6	34
1944	Sandusky	Erie	do	165	1.75	4.3	9.3	13.7	7	41
1989	do	do	do	165	1.33	4.9	8.2	9.7	6	65
1990	do	do	do	168	1.30	3.5	11.4	14.0	7	94
2979	do	do	do	168	1.33	3.8	10.5	13.1	8	58
4378	do	do	do	165	1.46	4.4	9.0	10.4	8	25
5554	do	do	do	168	1.05	3.9	10.2	17.3	10	17
5753	Castalia	do	Dolomite	165	1.85	5.6	7.2	13.9	7	38
6055	do	do	Limestone	172	.50	5.5	7.3	13.7	7	41
6056	Akron Junction	do	Cherty limestone	168	.20	5.3	7.6	19.5	10	27
2895	Wilmer	do	Calcareous sandstone	153	4.70	6.8	5.9	(1)	(1)	66
663	Columbus	Franklin	Limestone	159	3.25	6.7	6.0	(1)	(1)	59
664	do	do	do	162	1.70	6.9	5.8	(1)	(1)	29
666	do	do	do	156	2.60	3.8	10.6	(1)	(1)	74
2896	do	do	do	168	.69	3.8	10.5	15.9	6	55
3077	do	do	do	165	1.58	3.1	12.8	17.0	6	105
3356	Marble Cliff	do	do	165	1.45	4.0	10.1	16.0	10	96
3766	Columbus	do	do	168	1.98	4.3	9.3	15.5	9	61
5505	Marble Cliff	do	do	162	1.22	3.6	11.2	(1)	11	31
5506	do	do	do	162	2.14	7.2	5.6	(1)	7	31
5861	Columbus	do	do	165	1.05	3.8	10.4	14.5	6	39

Locality	Rock	Age	Stratigraphic Position	Thickness (ft)	Remarks
5630	do.	do.	Ferruginous sandstone.	162	
5631	do.	do.	Calcareous sandstone.	139	
5632	do.	do.	Dolomite.	165	
5633	do.	do.	Limestone.	165	
5634	do.	do.	do.	175	
5635	do.	do.	Sandstone.	168	
5636	do.	do.	Dolomite.	159	
5637	do.	do.	do.	159	
5638	do.	do.	do.	159	
5639	do.	do.	Limestone.	168	
5640	do.	do.	Dolomite.	165	
5641	do.	do.	do.	165	
5642	do.	do.	Argillaceous dolomite.	165	
5643	do.	do.	Chert limestone.	165	
5644	do.	do.	Argillaceous sandstone.	166	
5645	do.	do.	Limestone.	153	
5646	do.	do.	Calcareous sandstone.	159	
5647	do.	do.	Argillaceous limestone.	178	
5648	do.	do.	Blast furnace slag.	172	
5649	do.	do.	do.	156	
5650	do.	do.	Chert.	165	
5651	do.	do.	Limestone.	165	
5652	do.	do.	Dolomite.	153	
5653	do.	do.	Dolomite limestone.	175	
5654	do.	do.	Limestone.	156	
5655	do.	do.	Argillaceous limestone.	143	
5656	do.	do.	Blast furnace slag.	168	
5657	do.	do.	do.	168	
5658	do.	do.	Smelter slag.	165	
5659	do.	do.	Blast furnace slag.	165	
5660	do.	do.	Dolomite.	168	
5661	do.	do.	do.	162	
5662	do.	do.	do.	172	
5663	do.	do.	do.	175	
5664	do.	do.	do.	172	
5665	do.	do.	do.	172	
5666	do.	do.	Cherty dolomite.	168	
5667	do.	do.	Argillaceous dolomite.	168	
5668	do.	do.	Dolomite.	165	
5669	do.	do.	do.	172	
5670	do.	do.	Limestone.	165	
5671	do.	do.	Siliceous limestone.	168	
5672	do.	do.	Limestone.	168	
5673	do.	do.	Blast furnace slag.	175	
5674	do.	do.	do.	137	
5675	do.	do.	Limestone.	162	
5676	do.	do.	Sandstone.	153	
5677	do.	do.	Limestone.	172	
5678	do.	do.	do.	168	
5679	do.	do.	do.	168	
5680	do.	do.	do.	168	

² Exact locality not known.

¹ Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

OHIO—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				Pounds.	Pounds.					
3714	Piqua.....	Miami.	Limestone	168	.15	6.0	6.7	12.1	5	18
5880	do.....	do.	Crystalline limestone	172	.52	6.2	6.5	11.6	5	45
2015	Ludlow Falls.....	do.	Dolomite	172	.77	3.8	10.6	14.7	11	179
5891	Covington.....	do.	do.	172	1.84	3.8	10.4	12.4	8	29
5862	Piqua.....	do.	Marble	165	.92	7.8	5.2	5.6	3	23
1179	Madison Township.....	Montgomery.	Limestone	165	.74	10.2	3.9	11.2	7	101
1732	Dayton.....	do.	do.	175	.63	3.9	10.2	15.2	12	72
1763	do.....	do.	do.	162	.51	8.7	4.6	12.0	9	58
3257	Centerville.....	do.	do.	165	.70	6.2	6.5	9.3	5	60
3369	do.....	do.	do.	168	.96	7.4	5.4	14.8	6	46
1180	Butler Township.....	do.	Dolomite	165	1.22	7.5	5.4	14.8	10	48
7126	Zanesville.....	do.	Sandstone	153	2.10	43.9	.9	.0	1	(1)
8270	Grafton.....	Muskingum.	Siliceous limestone	162	1.72	4.2	9.5	18.3	13	95
779	Oak Harbor.....	do.	Dolomite	175	.21	6.1	6.5	(1)	(1)	31
778	do.....	Ottawa.	Limestone	165	.98	8.1	5.0	(1)	(1)	(1)
3541	do.....	do.	Dolomite	175	.67	4.2	9.4	15.7	11	12
5757	do.....	do.	do.	168	1.40	5.8	6.8	15.5	10	18
6052	do.....	do.	do.	172	1.03	5.9	6.8	14.7	5	24
6990	Freedom Township.....	Portage.	Limestone	165	1.39	4.6	8.7	15.1	13	46
6992	Atwater.....	do.	do.	168	1.11	4.7	8.5	17.4	8	49
7118	do.....	do.	Ferruginous sandstone	153	5.70	10.0	4.0	(1)	(1)	54
2893	New Paris.....	do.	Limestone	150	1.57	21.4	1.9	1.3	2	23
3181	New Paris (near).....	Preble.	Dolomite	175	.32	9.4	9.4	17.9	7	68
5930	Lewisburg.....	do.	Dolomite	172	.98	3.6	11.0	15.3	13	29
5980	New Paris.....	do.	Argillaceous dolomite	159	5.55	7.2	5.6	2.3	4	159
3183	do.....	do.	Dolomite	175	.47	2.6	15.4	15.8	14	28
4889	Bellevue.....	Ross.	Sandstone	165	3.69	(1)	(1)	15.8	11	16
5090	do.....	Sandusky.	Limestone	165	.95	4.1	9.9	12.3	6	22
5091	do.....	do.	do.	168	.97	6.3	6.4	13.3	10	35
1856	do.....	do.	do.	172	1.46	4.2	9.5	16.4	10	32
5092	do.....	Seneca.	Dolomite	165	1.29	6.9	5.8	13.8	14	75
2042	do.....	do.	do.	172	.96	6.7	6.0	15.3	7	49
5093	do.....	do.	do.	172	.55	10.8	8.7	12.4	7	54
7789	Fostoria.....	do.	Argillaceous dolomite	171	1.30	5.0	8.0	15.3	7	46
7776	do.....	do.	Dolomite	168	1.43	7.8	5.1	15.2	6	18
2477	Bloomville.....	do.	Argillaceous limestone	168	2.25	3.3	12.0	15.2	18	26
2478	do.....	do.	Limestone	172	.33	4.3	9.3	12.8	19	32
2532	do.....	do.	do.	168	2.12	4.5	8.8	13.8	8	43
5556	Bloomville.....	do.	do.	168	1.00	3.6	11.0	12.5	6	22

OKLAHOMA.

9281	do.	do.	156	3.33	4.3	9.3	13.5	7	20
2663	Stark.	do.	168	.55	3.9	10.2	15.8	9	24
2833	North Industry.	do.	153	4.33	5.2	7.8	13.8	14	26
828	Twinsburg.	do.	162	.80	3.1	13.0	(1)	8	21
6710	Canal Dover.	do.	(1)	(1)	16.5	2.4	11.4	5	300
4399	White Sulphur	do.	165	1.31	6.1	6.6	13.2	10	53
5555	Middlepoint.	do.	172	.76	7.5	7.5	16.3	13	16
6116	Willshire.	do.	159	1.05	3.5	3.5	9.2	4	20
4307	Cold Springs.	do.	162	3.59	11.5	4.4	11.4	6	21
4691	Carey	do.	165	1.34	5.9	6.8	8.8	3	(1)

4352	Chockie.	Afoka.	162	0.65	2.7	14.9	19.2	25	21
5853	Stringtown (near)	do.	153	2.91	6.3	6.4	18.8	5	20
5982	do.	do.	159	1.72	7.4	5.4	(1)	(1)	29
6374A	Chockie.	do.	162	.52	4.5	8.9	(1)	7	61
6374B	do.	do.	168	.73	(1)	(1)	16.0	(1)	78
9464	Stringtown.	do.	162	1.90	4.3	9.3	18.8	4	55
2950	Watonga.	Blaine.	143	3.34	38.2	1.0	4.8	13	4
3347	do.	do.	168	1.16	5.5	7.3	16.6	6	36
4366	Richards Spur.	Comanche.	168	.20	4.0	10.0	13.7	5	16
4703	Fort Sill.	do.	168	.54	(1)	(1)	14.8	6	18
4704	do.	do.	162	1.12	(1)	(1)	16.2	9	26
5251	Richards Spur.	do.	168	.62	3.9	10.4	18.7	15	11
4705	Fort Sill.	do.	162	1.14	(1)	(1)	16.2	7	78
4365	Cement.	Grady.	165	.66	4.1	9.9	19.3	21	10
4368	Granite City.	Greer.	165	.12	2.5	15.7	18.7	8	13
4369	do.	do.	165	.20	3.8	10.5	19.0	6	500+
4370	do.	do.	135	2.69	4.0	10.0	3.2	7	30
4356	Ravala.	Johnston.	165	.53	4.4	9.0	15.5	10	48
6034	(?)	do.	162	.81	5.7	7.0	14.7	(1)	83
9028	Wapanucka.	do.	156	2.74	5.6	7.0	(1)	8	17
7496	Tishomingo.	do.	165	.04	6.0	6.7	19.2	9	15
4355	Ravala.	do.	162	.08	3.3	12.0	19.0	(1)	14
5390	do.	do.	162	.39	4.2	9.0	(1)	25	31
4354	Tishomingo.	do.	190	.14	4.1	9.7	18.8	8	17
4346	Ponca City.	Kay.	143	5.06	(1)	(1)	0	5	47
4347	do.	do.	153	3.77	5.7	7.0	8.3	4	90
4348	Newkirk.	do.	143	6.79	9.9	9.9	0.0	3	54
4349	Uncas.	do.	150	5.29	9.3	4.3	0.0	7	32
5142	Ponca City.	do.	156	2.91	(1)	(1)	13.2	5	38
5143	do.	do.	156	3.03	(1)	(1)	12.3	5	38
5144	do.	do.	150	5.50	(1)	(1)	11.0	5	38
5145	do.	do.	150	4.65	(1)	(1)	8.6	5	22
5325	do.	do.	156	3.20	6.1	6.5	8.6	22	25
4367	Cold Springs.	do.	178	.24	2.8	14.3	18.8	22	

1 Test not made.

2 Exact locality not known.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916*—Contd.

OKLAHOMA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	Trench coefficient of wear.	Hardness.	Toughness.	Cementing value.
3872	Madill.....	Marshall.....	Limestone.....	Pounds. 162	Pounds. 2.54	4.9	8.2	13.0	5	27
6077	Garvin.....	McCurdian.....	do.....	156	1.98	10.0	4.0	0	4	8
4359	Douglas.....	Murray.....	Bituminous limestone.....	156	.86	4.2	9.6	(¹)	(¹)	500+
4362	Crusher.....	do.....	Limestone.....	168	.24	4.4	9.2	15.1	8	36
5376	do.....	do.....	do.....	172	.33	3.5	11.6	14.8	7	23
4383	Avant.....	Osage.....	do.....	162	.23	5.7	7.0	12.3	4	32
5325	Ripley.....	Payne.....	Dolomite.....	175	.59	4.6	8.7	14.6	7	44
4350	Hartshorne.....	Pittsburg.....	Limestone.....	168	.31	(¹)	(¹)	16.8	8	44
4351	do.....	do.....	do.....	165	1.14	4.4	9.1	16.6	13	132
4364	Ada.....	Pontotoc.....	Fossiliferous limestone.....	165	.41	9.0	4.4	8.2	3	42
8896	Fitzhugh.....	do.....	do.....	159	2.22	16.7	2.4	6.7	2	20
8857	do.....	do.....	do.....	168	.69	12.0	3.3	17.7	7	13
5993	Tuskahoma.....	Pushmataha.....	Calcareous chert.....	162	.45	5.8	6.9	19.4	6	40
3717	Tulsa.....	do.....	Sandstone.....	159	3.17	9.6	4.1	14.2	13	112
6468	Dewey.....	Washington.....	Limestone.....	165	1.37	5.0	8.0	17.3	5	42

OREGON.

2920	St. Helens.....	Columbia.....	Basalt.....	175	1.80	1.8	22.7	18.8	22	17
7357	Griffen Creek.....	Jackson.....	Altered basalt breccia.....	181	.38	1.8	22.7	18.5	24	33
980	Eugene (near).....	Lane.....	Basalt.....	168	2.30	5.9	6.8	7.9	7	(¹)
982	do.....	do.....	Olivine basalt.....	184	.72	2.8	14.3	10.7	6	225
7004	do.....	do.....	Volcanic breccia.....	172	3.23	(¹)	(¹)	17.0	4	175
1766	Salem.....	Marion.....	Basalt.....	175	.83	3.9	10.4	18.0	38	15
1135	Troutdale.....	do.....	do.....	168	2.32	3.7	10.8	16.0	19	24
1136	Portland (near).....	Multnomah.....	do.....	162	2.27	6.8	5.9	15.8	20	49
1137	do.....	do.....	do.....	172	2.01	3.8	10.6	16.4	26	99
1454	Newberg.....	do.....	do.....	172	1.64	(¹)	(¹)	18.4	30	5
7319	do.....	do.....	do.....	150	5.82	31.4	1.3	(¹)	(¹)	400
(²)	Pendleton.....	Umatilla.....	Basalt tufts.....	178	2.22	2.1	19.4	17.9	20	193
2070	Hillsboro.....	Washington.....	Olivine basalt.....	168	1.89	4.3	9.3	17.2	12	6
5354	(²).....	do.....	Basalt.....	165	1.26	4.2	9.1	17.9	15	6

PENNsylvania.

Locality	Adams	Limestone	172	0.20	4.9	8.2	14.2	9	64
Bittinger	do	do	165	1.25	2.0	20.4	17.2	25	36
Cumberland	do	do	175	.21	3.5	9.7	16.0	9	24
Hanover (near)	do	Siliceous limestone	178	.64	3.7	10.5	17.7	7	22
(²)	do	Feldspathic sandstone	168	.81	3.2	12.7	12.2	8	48
Bittinger	do	Sandstone	162	.81	(¹)	(¹)	13.9	12	27
Abbotstown	do	do	133	2.95	(¹)	(¹)	17.1	12	57
Cumberland	do	Slate	168	1.35	(¹)	(¹)	11.1	12	77
Littleton	do	do	165	2.10	(¹)	(¹)	1.1	7	101
do	do	do	172	.43	3.9	10.2	17.7	16	42
Oxford Township	do	Dolomite	162	.60	4.0	10.1	13.3	60	5
Berwick Township	do	Quartzite	165	.22	2.0	10.8	19.6	42	13
Menallen Township	do	Rhyolite	162	.35	1.9	21.1	19.5	34	22
1815	do	do	162	1.03	6.6	6.1	(¹)	(¹)	46
do	do	Chlorite schist	131	2.38	2.0	13.8	(¹)	10	260+
Hanover (near)	do	Altered basalt	175	1.18	2.0	20.4	17.0	9	500
(²)	do	do	181	.91	(¹)	(¹)	18.2	19	20
do	do	Diabase	187	.39	3.8	10.5	18.6	24	15
do	do	Hypersilene diabase	190	.25	2.5	16.0	18.7	12	20
do	do	Gabbroitic diabase	163	.32	4.7	8.5	17.9	5	42
do	do	Marble	168	.11	4.0	10.0	14.7	8	20
do	do	do	168	.37	5.8	6.9	13.3	3	21
do	do	do	168	.37	5.1	7.9	11.0	6	66
do	do	do	131	4.40	6.4	6.2	17.3	9	500+
do	do	Slag	206	2.36	4.9	8.1	(¹)	(¹)	97
Duquesne	do	do	168	.21	(¹)	(¹)	17.0	13	500+
Mt. Airy	do	Siliceous limestone	172	.29	4.2	9.5	16.4	7	64
Pittsburgh	do	Limestone	165	.83	5.9	6.7	16.7	12	37
Oakdale	do	do	172	.60	(¹)	(¹)	16.6	9	49
Coraopolis (near)	do	do	172	.27	4.5	8.9	15.3	3	19
Pittsburgh	do	do	168	.41	(¹)	(¹)	17.2	29	(¹)
do	do	Siliceous slate	172	.42	(¹)	(¹)	19.0	8	55
do	do	Pyroxene gneiss	181	.41	(¹)	(¹)	18.1	(¹)	55
do	do	Limestone	168	.26	5.0	8.0	(¹)	17	30
Ford City	do	do	168	.58	4.0	10.0	16.4	30	83
do	do	do	165	1.21	4.8	8.3	15.5	8	83
Kittanning	do	do	165	1.14	4.1	9.8	15.0	7	62
Franklin	do	do	168	.35	4.9	8.2	15.7	8	57
Kittanning	do	do	172	.46	4.7	8.5	16.2	7	37
2551	do	Craigville (near)	165	1.04	(¹)	(¹)	15.5	7	42
East Brady	do	do	165	.79	4.8	8.3	16.4	9	48
Kittanning	do	do	168	.52	5.1	7.8	14.8	6	25
Templeton	do	do	168	.23	6.3	6.8	15.8	6	42
Apollo	do	do	168	.58	2.9	13.6	16.6	9	109
Freeport	do	Siliceous limestone	168	.72	6.7	6.0	14.7	6	35
Beaver	do	Limestone	168	.43	3.5	11.4	16.5	110	61
Bedford	do	do	172	.31	(¹)	(¹)	16.7	10	2752
Waterside	do	do	172	.31	(¹)	(¹)	16.7	10	2752

Exact locality not known.

Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916.—Contd.

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
3851	Hyndman.....	Bedford	Limestone.....	Pounds. 172	Pounds. .45	3.4	11.8	17.2	15	63
5602	do.....	do.	Impure limestone.....	168	.22	2.9	13.7	14.3	6	39
5603	do.....	do.	Siliceous limestone.....	168	.22	4.1	9.7	16.5	10	45
2194	Bloomfield Township.....	do.	Quartzite.....	176	1.39	4.6	8.7	17.4	9	12
2331	South Woodbury Township.....	do.	Dolomite.....	178	.83	3.4	11.9	15.8	11	24
1702	(1)	Berks	Quartzite.....	162	.47	2.5	15.7	(2)	(2)	7
1947	Birdsboro.....	do.	Diabase.....	184	.74	1.9	20.8	18.0	12	69
2248	Bally.....	do.	do.....	187	.45	3.7	15.0	18.2	10	52
5573	Bechtelsville.....	do.	Gabbroitic diabase.....	187	.81	3.9	10.3	18.3	12	37
5585	Birdsboro.....	do.	Diabase.....	184	.14	2.0	20.0	18.0	26	33
5626	Birdsboro (near).....	do.	do.....	187	.40	2.4	16.8	18.8	17	66
7414	Douglaville.....	do.	Altered diabase.....	187	.41	2.8	14.1	18.5	19	104
8786	Trap Rock Station.....	do.	Gabbroitic diabase.....	184	.59	3.2	12.5	17.9	10	36
5632	Birdsboro (2½ miles south of).....	do.	Altered diabase.....	184	.34	2.0	19.8	18.2	21	59
1983	Seisholtzville.....	do.	Granite.....	168	.35	3.2	12.7	18.0	18	23
5361	Reading.....	do.	Hornblende granite.....	172	1.05	2.0	20.0	18.3	24	37
8243	Baro.....	do.	Weathered granite.....	162	.82	(2)	(2)	19.0	10	83
2033	do.....	do.	Altered diorite.....	209	.71	2.3	17.1	18.7	16	50
8242	do.....	do.	do.....	197	.61	2.4	16.5	19.0	12	30
2192	(1)	do.	Slate.....	172	.54	1.6	24.4	18.4	40	35
3121	(1)	do.	Clay slate.....	168	.33	2.0	19.6	18.8	56	29
2659	Monocacy.....	do.	Gabbro.....	184	.67	2.4	16.4	18.6	19	72
2660	do.....	do.	Altered gabbro.....	181	.75	5.9	6.8	(2)	(2)	115
2661	do.....	do.	Gabbro.....	190	.37	2.2	18.2	18.2	13	14
3434	Birdsboro.....	do.	do.....	187	.47	1.5	26.7	18.6	9	31
3435	Birdsboro.....	do.	do.....	184	.67	1.8	21.7	18.6	23	15
2949	Birdsboro.....	do.	Slag.....	125	4.26	11.8	3.4	10.7	4	44
3122	Douglaville.....	do.	Argillaceous sandstone.....	159	3.48	2.0	20.2	18.7	36	194
3167	Douglaville.....	do.	Sandstone.....	175	.63	2.5	16.0	17.3	38	43
5569	(1)	do.	Ferruginous sandstone.....	168	.43	1.6	24.7	19.2	35	34
5720	Little Oley.....	do.	do.....	156	2.34	1.8	21.1	18.2	35	36
3355	do.....	do.	Dolomite.....	168	.12	3.6	11.1	16.2	11	29
8935	Reading.....	do.	Argillaceous dolomite.....	168	.39	3.3	12.3	17.7	5	31
do.....	do.....	do.	Dolomite.....	178	.42	5.7	7.0	(2)	(2)	19
9615	Douglaville.....	do.	Altered basalt breccia.....	168	1.12	4.4	29.4	19.3	34	27
7610	Lyons.....	do.	Weathered chert.....	156	2.66	5.4	7.5	(2)	(2)	0
2034	Altoona (near).....	do.	Limestone.....	168	.63	5.4	7.5	11.3	8	57
2384	Altoona.....	do.	do.....	168	.39	3.2	12.5	14.2	7	27

2406	do	do	168	32	2.8	14.5	16.7	11
2407	do	do	168	91	4.3	9.3	15.3	6
2407	Carthame Township	Siliceous limestone	168	66	3.6	11.2	16.7	22
2421	Albany Township	Limestone (siliceous)	168	46	4.9	8.2	13.7	45
2432	Holidaysburg	Limestone	172	69	3.7	10.7	17.3	26
2483	do	do	172	80	4.9	13.2	17.1	53
2834	do	do	168	10	3.2	12.5	16.5	23
2839	do	do	168	40	6.0	6.8	13.7	47
8724	Junata	Crystalline limestone	168	40	6.0	6.8	13.7	4
8725	do	Argillaceous limestone	168	45	6.0	6.8	13.7	(2)
8726	do	Feldspathic sandstone	165	81	(3)	(3)	(3)	(3)
8727	do	Sandstone	162	63	2.3	17.4	18.2	11
8728	do	Dolomite	172	84	3.3	12.0	17.2	12
2482	Holidaysburg	do	172	26	3.1	13.0	16.5	10
2482	do	do	178	78	3.3	12.2	16.8	10
3745	Tyrone Township	do	178	41	3.5	11.3	15.9	63
3745	Logan Township	Siliceous limestone	168	63	4.3	9.4	13.2	14
2068	Wells	Limestone	168	64	3.7	10.8	16.3	7
2419	Wyalusing Township	do	168	39	3.7	10.8	16.3	4
2535	do	do	168	39	4.2	9.5	13.2	8
3080	Camptown	do	168	68	3.9	10.2	16.0	42
3119	Wysox Township	do	168	84	3.1	12.7	16.3	9
3120	do	do	168	49	3.1	12.7	16.3	12
3123	do	do	168	26	5.3	7.6	14.3	7
3241	Shores Hill	Limestone	162	51	4.2	9.6	15.6	8
3715	Sheshequin Township	Siliceous limestone	168	22	6.7	6.0	16.0	10
3716	do	do	168	32	5.3	7.6	14.3	35
3719	Rome Township	do	168	26	4.2	9.6	15.6	45
3802	Wysox Township	do	168	22	6.7	6.0	16.0	35
7730	East Smithfield	do	168	20	3.7	10.9	17.8	49
2069	Wells	do	168	24	3.3	12.1	17.0	13
3097	Wysox Township	do	168	40	6.8	5.9	15.7	10
2541	Wyalusing Township	do	168	86	(2)	(2)	(2)	35
731	Rock Hill	Fossiliferous limestone	165	89	2.9	13.8	17.3	31
5408	Lathaska	Feldspathic sandstone	165	165	4.7	8.5	17.9	54
6359	do	Calcareous sandstone	168	63	1.2	34.5	18.5	27
8660	Rock Hill	Fossiliferous dolomite	193	12	2.0	19.8	18.5	58
3200	Shelly	Diabase	184	17	2.0	20.0	17.5	30
5386	New Hope	Gabbroitic diabase	184	33	2.0	20.0	17.5	23
855	do	do	190	29	3.7	10.8	18.3	8
855	do	Hypersthene diabase	187	34	2.4	16.5	18.5	22
979	Bensalem	do	184	33	2.2	17.9	18.5	(2)
1000	do	Granite gneiss	168	10	3.0	13.2	16.4	(2)
1000	do	Hornblende schist	178	18	2.9	13.9	16.4	27
1038	Rushland	Mica schist	172	13	4.1	9.8	17.5	13
1943	Philadelphia	Siliceous limestone	168	49	2.3	17.3	17.0	20
7277	Rushland	Impure limestone	175	32	4.2	9.6	16.0	80
6616	do	Siliceous limestone	172	39	2.5	15.9	17.5	69
1365	Bridge Valley	Slate	168	34	2.9	13.9	18.3	38
1245	do	Siliceous slate	168	53	4.2	9.5	17.3	18
1245	do	Argillaceous sandstone	165	165	2.8	14.1	16.5	48
1246	do	Sandstone	153	3.04	2.7	15.0	16.6	63
4929	Newton	do	168	51	3.6	11.0	18.4	17
2064	Edison post office	Clay shale	168	50	3.2	12.6	17.7	27
2223	Quakertown	Gabbro	187	43	1.7	24.1	18.6	15
2742	Rock Hill	do	168	22	1.9	20.8	18.8	21
2727	West Windfield	Limestone	168	23	3.7	10.8	16.1	50

Exact locality not known.

² Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
2894	East Taylor Township.	Cambria.	Calcareous sandstone.	168	.38	2.8	14.2	17.5	11	60
5221	Johnstown.	do.	Limestone.	168	.38	2.8	14.4	16.8	14	26
2267	East Mauch Chunk.	Carbon.	Feldspathic quartzite.	168	.31	2.4	16.4	19.3	15	15
7424	(1)	do.	do.	165	.24	2.6	15.1	18.8	13	45
7371	(1)	do.	Slag.	143	4.90	12.2	3.3	15.3	7	25
8625	Bazard.	do.	Slag.	178	2.18	6.6	6.0	17.3	6	23
2522	Palmerston.	do.	Slag.	168	3.47	12.2	3.3	15.0	8	17
6766	Bellefonte.	Center.	Calcareous sandstone.	165	.75	4.5	8.9	15.3	7	36
1163	do.	do.	Limestone.	168	.31	3.7	6.9	16.3	11	27
2251	do.	do.	do.	168	.46	3.8	10.9	14.7	6	28
2431	Spring Township.	do.	do.	168	.45	4.5	8.8	13.6	6	21
339	Cedar Hollow.	do.	do.	168	.45	4.5	8.8	13.6	(2)	(2)
1076	East White Hall Township.	Chester.	Dolomite.	178	.16	3.8	10.6	14.9	7	48
3355	Exton.	do.	do.	178	.20	4.2	9.5	16.3	9	25
3757	Cedar Hollow.	do.	do.	178	.48	4.2	9.6	16.3	9	17
964	Coatesville.	do.	do.	178	.17	4.5	9.0	16.3	8	17
2712	Howellsville.	do.	Marble.	178	.16	3.8	10.5	15.9	9	77
3540	Coatesville.	do.	do.	172	.30	4.5	9.0	14.7	5	27
5344	Coatesville.	do.	do.	175	.10	4.2	9.4	13.0	8	69
6110	Cedar Hollow.	do.	Dolomitic marble.	172	.24	5.9	6.8	11.8	5	15
7427	(1)	do.	do.	175	.38	4.7	8.4	16.0	10	21
965	Coatesville.	do.	do.	178	.22	2.9	14.0	14.8	8	23
1077	East White Hall Township.	do.	Limestone.	175	.22	4.7	8.5	15.4	9	21
2710	Avondale.	do.	Dolomitic limestone.	178	.31	3.9	10.3	15.7	7	18
3349	West Grove (near).	do.	Crytalline limestone.	172	.41	13.2	3.0	14.0	3	32
3746	Knickerbocker.	do.	do.	172	.31	4.2	9.6	13.8	6	53
1172	St. Peters.	do.	Limestone.	172	.37	4.0	10.0	17.1	15	22
1308	Spring City.	do.	Gabbro.	190	.46	1.3	30.8	18.7	17	12
1333	St. Peters.	do.	Feldspathic sandstone.	156	1.74	3.8	10.6	18.1	15	207
1546	Coatesville.	do.	do.	172	.27	5.6	7.2	18.0	27	69
1713	Avondale.	do.	Hornblende gneiss.	190	1.24	3.1	13.0	16.6	8	38
3345	Glenmore.	do.	Biotite gneiss.	162	.42	5.6	7.1	17.7	7	49
6866	Dowington.	do.	Hornblende gneiss.	190	.20	3.4	11.7	18.3	15	26
6949	Marcus Hook.	do.	Biotite gneiss.	165	.31	4.1	9.9	18.2	6	42
9068	Dorland.	do.	do.	172	.41	4.2	9.6	18.1	8	16
1682	Glenmore.	do.	Sericite gneiss.	165	.16	3.5	11.4	18.7	13	9
1683	do.	do.	Altered diabase.	193	.32	2.2	18.0	19.0	36	(2)
2043	do.	do.	Diabase.	187	1.00	8.5	18.4	18.4	8	16
1955	Atglen.	do.	Quartzite schist.	165	.83	2.3	17.5	19.0	32	(2)
					.47	3.0	13.2	18.7	7	12

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916—Contd.

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
5903	Rockville.....	Dauphin.....	Sandstone.....	153	8.68	5.6	7.1	18.7	7	13
5905	do.....	do.....	Feldspathic sandstone.....	165	6.7	2.2	17.9	17.8	26	68
6104	Hummelstown.....	do.....	Calcareous sandstone.....	168	5.3	4.2	9.5	16.0	19	19
5902	Rockville.....	do.....	Quartzite.....	188	4.5	2.2	17.9	19.1	20	14
5904	do.....	do.....	do.....	166	3.7	3.0	16.7	19.3	23	22
722	(1).....	do.....	Dolomite marble.....	175	4.5	2.4	13.2	17.3	(2)	68
5906	Glen Mills.....	Delaware.....	Eclogite.....	(2)	(2)	2.8	14.5	(2)	9	(2)
4098	do.....	do.....	do.....	187	10	1.8	12.7	(3)	(3)	23
4092	do.....	do.....	do.....	193	10	1.8	22.7	18.5	28	10
5897	do.....	do.....	Horriblende gneiss.....	181	19	2.7	14.8	18.3	10	23
7857	Lenni.....	do.....	Biotite gneiss.....	171	20	2.8	14.3	18.6	13	14
8021	(1).....	do.....	do.....	175	42	2.5	16.1	18.7	12	28
1780	Glen Mills.....	do.....	Schist.....	200	26	2.7	14.7	18.7	24	24
7780	do.....	do.....	Horriblende schist.....	187	54	3.8	10.5	16.7	7	43
5971	Lansdale.....	do.....	do.....	198	15	1.9	20.1	18.3	18	22
5970	Glen Mills.....	do.....	Pyroxene quartzite.....	190	24	2.0	20.4	18.5	22	12
2800	do.....	do.....	do.....	193	34	2.2	17.9	17.0	12	24
2626	do.....	do.....	Diorite.....	172	11	3.8	10.7	(2)	(2)	51
1354	Kersey.....	Elk.....	Limestone.....	168	49	5.0	8.0	16.0	5	41
5870	St. Marys (near).....	do.....	Alfonsine limestone.....	156	95	5.0	8.0	16.7	7	38
5881	Daguerichonda.....	do.....	Feldspathic sandstone.....	168	26	2.3	17.1	18.3	14	60
1925	Dunbar.....	Fayette.....	Limestone.....	168	70	4.4	9.2	13.0	5	102
1941	do.....	do.....	do.....	168	52	4.0	10.0	15.7	8	109
1936	Union Town.....	do.....	do.....	168	41	2.6	13.4	16.0	9	109
1967	Farmington post office.....	do.....	do.....	168	80	2.3	17.7	17.0	9	108
2028	Humbertown post office.....	do.....	do.....	168	31	2.5	17.2	14.3	(2)	90
2040	Dunbar.....	do.....	do.....	168	65	3.1	13.1	15.9	10	67
2041	Somerfield (near).....	do.....	do.....	168	42	3.9	10.4	16.5	9	76
2079	Masonstown.....	do.....	do.....	168	72	2.6	13.4	16.2	9	105
2226	Somerfield (3 miles from).....	do.....	do.....	168	48	2.2	13.4	16.2	5	65
2228	Uniontown (7 miles from).....	do.....	do.....	168	24	2.4	16.7	16.3	13	65
2612	Connellsville (3 miles from).....	do.....	do.....	168	51	2.5	11.3	16.3	4	90
3130	Fayette City.....	do.....	do.....	168	15	2.9	13.7	17.3	12	23
3161	Brownsville (near).....	do.....	Siliceous limestone.....	168	32	3.4	11.9	17.8	11	27
3789	Uniontown.....	do.....	do.....	168	26	3.1	13.0	17.5	17	30
3806	do.....	do.....	Limestone.....	168	84	3.0	13.6	16.6	7	43
3852	Evans.....	do.....	do.....	168	27	2.4	16.4	17.7	15	31
3853	Dunbar.....	do.....	do.....	168	34	3.6	16.4	17.7	7	31
5290	Dunbar Township.....	do.....	Siliceous limestone.....	168	23	3.5	11.6	15.7	7	14
5692	Uniontown.....	do.....	Limestone.....	168	23	3.5	11.6	15.7	7	14

6097	Bidwell.....	do.	do.	168	.90	3.0	13.3	15.7	12	74
6629	Connellsville.....	do.	Siliceous limestone.	168	.06	2.5	15.9	16.3	18	124
9347	do.	do.	Limestone.	168	.47	3.2	17.3	17.3	12	15
9402	Uniontown (near).....	do.	Siliceous limestone.	168	.37	3.5	11.4	17.2	15	119
9374	do.	do.	do.	165	.19	3.0	13.3	18.2	11	34
2080	Masontown.....	do.	do.	156	3.14	10.1	3.9	(2)	3	500+
4025	Bluestone.....	do.	Calcareous sandstone.	168	.20	2.6	15.6	18.0	11	46
5771	Indian Creek station.....	do.	do.	168	.28	3.3	12.0	17.0	17	66
2089	Waynesboro (near).....	do.	Siliceous limestone.	175	.77	3.6	11.1	17.5	9	48
2677	Richmond Furnace.....	Franklin	Siliceous limestone.	175	.21	2.4	16.4	17.3	18	75
3142	Mercersburg.....	do.	Limestone.	168	.33	4.3	9.3	15.8	9	14
2600	Guilford.....	do.	do.	162	.40	4.3	9.4	19.2	9	17
3141	Montgomery Township.....	do.	Quartzite.	178	.52	3.2	12.6	17.9	10	24
2113	Brady Township.....	do.	Dolomite.	168	.41	5.0	8.0	15.5	5	87
2119	Brady Township.....	Huntingdon.	Limestone.	168	.52	4.1	9.8	15.3	5	69
2126	Huntingdon.....	do.	do.	175	.22	3.1	13.0	16.7	11	50
2211	Brady Township.....	do.	do.	163	.21	6.1	10.0	16.0	9	96
2212	do.	do.	do.	172	.21	4.0	10.0	15.0	9	83
2243	do.	do.	do.	168	.37	5.4	17.4	16.0	7	92
2243	Warriors Mark.....	do.	Siliceous limestone.	175	.52	2.5	15.7	18.2	14	22
2275	Mount Uniontown.....	do.	Limestone.	168	.62	4.2	9.5	14.4	6	31
2337	Shirley Township.....	do.	do.	168	.36	4.1	9.8	15.2	6	81
2341	(1).....	do.	do.	163	.57	3.7	10.8	15.8	6	49
2342	(1).....	do.	do.	168	.24	4.5	9.0	17.3	6	97
2345	Mill Creek.....	do.	do.	168	.94	4.8	8.3	15.2	5	31
2401	Union Furnace.....	do.	do.	168	.23	3.8	10.6	16.2	7	50
5337	Huntingdon.....	do.	do.	168	.42	4.8	8.3	15.6	7	28
7432	do.	do.	Argillaceous limestone.	172	.52	(2)	(2)	16.0	4	39
2120	Brady Township.....	do.	Sandstone.	(2)	(2)	6.5	6.2	18.5	5	23
2121	do.	do.	do.	(2)	(2)	(2)	(2)	16.7	7	112
2092	Huntingdon.....	do.	Feldspathic sandstone.	168	.42	2.2	18.3	17.5	24	24
5604	Water Street.....	do.	do.	168	.70	2.3	17.2	18.7	20	50
5726-1	Huntingdon.....	do.	do.	165	.49	2.5	16.3	18.1	21	42
5726-2	do.	do.	do.	165	.69	3.3	12.1	18.6	14	57
2127	do.	do.	Siliceous dolomite.	168	.53	4.5	9.0	(2)	93	29
2442	Union Furnace (near).....	do.	Dolomite.	178	.16	3.5	11.3	16.1	11	75
2834	(1).....	Indiana.	Limestone.	168	.06	2.7	14.7	16.8	13	47
2835	do.	do.	Sandstone.	150	3.26	18.8	2.1	5.7	5	25
5495	Mifflin.....	do.	Argillaceous dolomite.	172	.31	4.4	9.1	16.3	9	420
1888	Scranton.....	do.	Sandstone.	165	.34	2.0	20.0	17.7	15	22
2047	Dunmore.....	do.	do.	162	.88	2.5	16.1	18.3	9	34
2317	Glenburne.....	do.	Ferruginous sandstone.	168	1.22	4.0	9.9	15.4	15	7
1534	Eden Township.....	do.	Gabbro.	190	.34	2.4	16.8	18.3	18	61
1688	Bart Township.....	do.	Diabase.	187	.24	1.7	23.8	18.5	39	63
1847	Lancaster.....	do.	do.	187	.22	1.8	22.7	19.1	39	61
1847	Lancaster.....	do.	Olivine diabase.	190	.35	3.7	10.9	17.6	13	51
2026	Cornwall (near).....	do.	Diabase.	193	.28	1.9	20.8	18.3	30	25
2945	Lancaster.....	do.	do.	187	.50	1.8	22.5	18.7	29	14
5326	Elizabethtown.....	do.	do.	193	.32	1.8	21.7	17.9	18	14
1869	Strasburg Township.....	do.	Dolomite	178	.45	5.0	8.0	14.3	4	20

* Test not made.

1 Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
1590	Refton post office.	Lancaster.	Dolomite.....	Pounds. 178	Pounds. .24	3.9	10.2	11.8	9	23
1614	do.	do.	do.	178	1.14	4.7	8.4	12.7	6	45
6700	Rockville.	do.	Argillaceous dolomite.	178	.35	4.5	8.8	16.0	4	83
6283	Maytown.	do.	Limestone.	165	.33	6.0	6.7	15.8	5	46
6567	Salisbury.	do.	Siliceous limestone.	168	.37	3.7	10.7	14.3	9	67
7044	Millway.	do.	Limestone.	172	.18	3.9	10.4	16.5	8	12
7047	Rothville.	do.	do.	178	.16	4.3	9.4	16.9	10	11
7048	Littitz.	do.	do.	168	.17	5.0	8.0	12.7	4	21
7809	Rheims (West Donegal Township).	do.	Marble.	174	.52	4.9	8.2	16.7	16	25
5548	Quarryville.	do.	Dolomite.	168	.20	5.2	7.8	14.5	5	24
6113	Gap.	do.	Dolomitic marble.	181	.22	7.6	5.3	12.7	4	18
6663	do.	do.	do.	181	.23	4.7	8.6	11.8	4	36
6670	do.	do.	do.	178	.08	4.8	8.3	13.6	6	41
7091	Littitz.	do.	Marble.	172	.30	4.2	9.5	11.5	5	69
6568	Salisbury.	do.	Calcareous schist.	181	.28	15.2	2.6	(¹)	(¹)	40
8139	Lancaster.	do.	do.	172	.40	4.0	9.9	15.5	5	78
2490	Ellwood City (near).	Lawrence.	Limestone.	168	.64	4.5	8.9	(¹)	(¹)	42
2686	Chevron.	do.	do.	168	.39	4.4	9.1	15.8	8	19
2717	Wayne Township.	do.	do.	168	.45	3.9	10.2	16.5	9	88
4322	Rock Point (near).	do.	do.	168	.48	5.1	7.9	15.6	7	38
5557	Walford.	do.	do.	172	.25	4.9	8.2	16.5	6	26
2374	Sheridan.	Lebanon.	do.	172	.12	3.6	11.2	16.5	7	39
6632	Cornwall.	do.	Dolomitic limestone.	178	.50	4.1	9.7	13.5	8	133
6593	South Lebanon Township.	do.	Limestone.	168	.31	4.1	9.8	13.3	6	131
6682	Lebanon.	do.	Argillaceous limestone.	168	.34	4.3	9.3	12.9	9	48
6887	do.	do.	Siliceous limestone.	172	.20	3.8	10.5	16.1	9	50
7540	do.	do.	do.	169	.20	4.3	9.3	15.8	3	44
7653	do.	do.	Argillaceous limestone.	172	.17	3.2	12.5	14.7	7	42
6532	Annville.	do.	Carbonaceous dolomite.	175	.83	2.9	13.6	17.0	7	65
6612	Lebanon.	do.	Dolomite.	175	.48	3.7	10.9	17.6	20	76
1207	Vera Cruz.	Lehigh.	Gneiss.	172	.46	(¹)	(¹)	18.6	14	16
1692	Allentown.	do.	Dolomite.	175	.07	6.9	5.8	18.6	20	16
6327	Catasqua.	do.	Argillaceous dolomite.	175	.17	2.4	16.7	(¹)	(¹)	26
2662	Vera Cruz.	do.	Syenite.	172	.36	2.3	17.7	18.3	16	19
697	Wilkes-Barre.	do.	Sandstone.	168	.46	3.4	11.2	(¹)	(¹)	202
1074	do.	Luzerne.	Feldspathic sandstone.	168	.32	2.8	14.6	18.6	37	34
1114	do.	do.	do.	168	.37	1.8	22.9	17.0	23	55
1396	Conyngham.	do.	Sandstone.	165	1.60	3.3	12.1	15.6	10	283
1698	do.	do.	do.	168	1.12	3.7	10.9	15.7	13	41

1874	White Haven	do.	165	32	1.0	40.8	18.5	23
2993	Wilkes-Barre.	Feldspathic sandstone	168	.44	2.3	17.7	18.8	28
2577	Lehigh Tannery	do.	168	.11	2.0	20.4	18.3	32
6305	Duryea Borough	Calcareous sandstone	168	.46	2.4	16.4	15.5	37
6308	Pittston (near)	do.	165	.55	3.0	13.3	16.3	123
7680	Waywallopen	Feldspathic sandstone	168	.31	1.7	23.0	18.3	100
7681	Pittston	Calcareous sandstone	168	.35	2.9	13.8	18.6	25
8406	(2)	Feldspathic sandstone	165	.42	2.2	13.4	19.2	60
1075	Wilkes-Barre	Slate	172	.49	(1)	(1)	18.0	17
1252	(2)	Feldspathic quartzite	168	.18	1.8	22.6	18.0	22
1278	White Haven	do.	168	.15	2.1	13.8	18.6	26
7679	do.	do.	168	.40	1.9	21.9	18.7	20
914	Williamsport	Sandstone	162	2.00	2.9	13.6	16.4	13
1653	Coganshouse Township	Calcareous sandstone	162	1.09	4.8	8.3	13.0	81
3783	Pitt Township	Sandstone	162	.75	3.3	12.3	17.7	50
4025	Williamsport	Feldspathic sandstone	162	2.12	(1)	(1)	13.7	20
4026	do.	do.	162	2.46	(1)	(1)	12.3	13
4027	do.	do.	162	2.13	(1)	(1)	12.3	8
4735	Larryville	do.	162	1.10	4.6	8.7	18.2	8
5721	Hughesville	Argillaceous sandstone	168	.80	3.3	12.1	12.3	22
7445	Picture Rocks	Feldspathic sandstone	168	1.72	2.6	15.5	19.2	10
1103	Williamsport	Shale	172	.87	(1)	(1)	13.9	19
1139	do.	Limestone	168	.36	7.4	5.4	14.6	3
1161	do.	do.	168	.24	5.8	6.8	16.4	13
1164	Porter Township	do.	168	.58	4.6	8.8	16.2	21
1279	Montgomery (near)	do.	172	.78	4.9	8.2	8.7	8
1872	Jersey Shore	do.	172	.38	4.1	9.8	17.3	23
2751	do.	do.	168	(1)	5.1	7.8	14.3	10
3868	Williamsport	Argillaceous limestone	168	.40	4.8	8.3	17.3	8
6153	Porter Township	do.	165	.58	3.8	10.6	18.0	87
6154	do.	do.	168	.56	4.2	9.4	17.3	16
6155	do.	do.	172	1.26	5.4	7.4	12.5	22
6156	do.	Limestone	168	.44	4.6	8.6	16.0	24
6157	do.	do.	178	.43	3.0	13.5	17.5	11
6158	do.	do.	168	.65	3.2	12.8	14.7	8
6991	Lower Fairfield	do.	168	.18	4.7	8.5	16.2	24
6880	Muncy Township	Limestone	172	.22	7.4	5.4	13.0	7
7322	do.	Carbonaceous limestone	168	.47	6.0	6.7	15.7	32
7453	Loyalsock Township	Diabase	168	1.47	4.1	9.8	16.8	6
1121	Newberry	do.	190	.25	(1)	(1)	18.6	4
1122	do.	do.	190	.19	(1)	(1)	18.7	8
7477	Montourville	Calcareous chert	165	.96	4.9	8.2	19.7	31
1745	Linden	Dolomite	175	.51	5.4	7.4	15.3	40
6813	Sharpville	Blas-furnace slag	156	4.32	19.1	2.1	14.5	13
2224	Nagney	Limestone	168	.38	4.9	8.1	15.0	48
2531	Reedville	do.	165	.83	5.5	7.2	17.9	257
4396	Mitroy	Siliceous limestone	172	.42	3.0	13.2	17.0	10
3224	Lewistown	Limestone	168	.29	3.1	9.7	18.3	4
8453	do.	Argillaceous limestone	168	.35	2.3	17.4	16.8	17
5438	(1)	Sandstone	165	.32	4.1	9.8	17.4	25

¹ Test not made.

² Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
1359	Tobyhanna.....	Monroe.....	Feldspathic sandstone.....	168	.25	3.7	10.8	18.4	19	30
1816	Smithfield.....	do.....	Calcareous slate.....	168	.33	3.9	10.3	15.0	14	60
365	Habors.....	Montgomery.....	Ferruginous sandstone.....	165	.83	4.0	10.0	(1)	(1)	(1)
2322	Bridgeport.....	do.....	Feldspathic sandstone.....	159	1.32	3.1	12.7	19.4	14	253
2684	Green Lane.....	do.....	Calcareous sandstone.....	168	1.85	2.0	20.4	18.7	23	22
5132	Salford.....	do.....	Argillaceous sandstone.....	172	1.22	2.2	17.9	15.8	6	23
6885	Phoenixville (near).....	do.....	Feldspathic sandstone.....	181	.34	2.0	19.6	18.8	44	52
7120	Linfield.....	do.....	Ferruginous sandstone.....	156	2.53	3.0	13.3	18.5	9	131
1037	Green Lane.....	do.....	Slate.....	172	.68	2.6	15.2	17.9	17	179
1895	Fraconia Township.....	do.....	do.....	168	.24	2.5	15.9	16.5	6	241
2039	Hendricks Station.....	do.....	Calcareous slate.....	165	1.21	2.2	17.9	16.4	8	83
2049	Green Lane.....	do.....	Indurated slate.....	168	.75	1.7	23.5	18.9	40	23
2172	do.....	do.....	Slate.....	175	.59	2.6	15.5	15.4	10	59
2624	Ambler.....	do.....	do.....	173	.73	4.5	8.8	16.2	6	96
2683	Green Lane.....	do.....	do.....	172	.21	2.1	19.0	18.6	38	20
5680	Sunneystown.....	do.....	do.....	172	.24	2.6	15.4	18.7	24	20
5197	Green Lane.....	do.....	Siliceous slate.....	172	.57	2.9	13.6	18.9	52	34
6459	Pottstown.....	do.....	do.....	172	.76	2.1	19.4	18.5	13	85
6460	do.....	do.....	do.....	172	.75	2.1	18.9	18.3	13	61
6639	Lower Gwynedd.....	do.....	do.....	168	1.24	2.7	15.0	13.5	17	65
7669	Upper Salford Township.....	do.....	Siliceous slate.....	171	1.37	4.4	9.0	18.2	11	31
8728	Green Lane.....	do.....	Micaceous slate.....	172	.74	2.0	19.5	17.5	17	29
6638	White Marsh Township.....	do.....	Feldspathic quartzite.....	162	.71	3.3	12.0	18.9	(1)	186
1316	Port Kennedy.....	do.....	Diabase.....	181	.26	2.8	14.5	17.1	8	40
2558	Green Lane.....	do.....	do.....	193	.31	2.7	14.9	17.1	33	45
2682	do.....	do.....	Altered diabase.....	181	.28	1.6	25.0	18.5	40	48
2760	do.....	do.....	Diabase.....	187	.42	1.4	28.6	18.5	33	45
1315	Port Kennedy.....	do.....	Dolomite.....	178	.22	4.2	9.5	14.7	11	13
2021	Ivory Rock (Plymouth Township).....	do.....	Gabbro.....	193	.82	2.5	15.8	17.5	12	15
2092	Green Lane.....	do.....	Pyroxene granolite.....	190	.34	2.5	15.8	19.2	12	32
2261	Paper Mills Station.....	do.....	Aplite granite.....	165	.16	2.7	14.6	19.6	14	17
8050	Bryn Athyn.....	do.....	Granite.....	175	.22	4.6	8.7	19.6	6	17
8689	Pencoyd.....	do.....	Limestone.....	175	.32	(1)	9.6	18.3	12	13
2274	Conshohocken (near).....	do.....	Granite.....	178	.53	4.2	9.6	16.0	8	21
3405	Pottstown.....	do.....	Siliceous limestone.....	168	.80	3.0	13.4	17.2	14	30
8114	Norristown.....	do.....	do.....	175	.50	3.4	11.6	17.4	10	46
4601	Bethayres.....	do.....	Gneiss.....	165	.32	4.8	8.3	18.7	17	59
7853	Huntingdon Valley.....	do.....	Granite gneiss.....	168	.16	5.1	7.8	18.8	20	9

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.*

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
5833	Philadelphia.....	Philadelphia.	Argillaceous sandstone.....	Pounds. (1) 181	Pounds. (1) 21	(1) 3.8	(1) 0.5	15.8	15	(1) 15
6896	Frankford.....	do.	Hornblende gneiss.....	168	.91	3.2	0.5	17.8	9	36
2932	Greentown.....	Pike.	Feldspathic sandstone.....	165	.74	3.2	7.7	17.5	8	28
4383	do.	do.	do.	159	3.16	5.5	6.2	17.7	8	75
4382	Portage Township.....	Porter.	Sandstone.....	168	.91	5.4	7.4	15.7	8	201
2210	Sittler.....	Schenck.	Calcareous slate.....	168	.75	2.3	17.1	17.7	15	37
2239	Ringtown.....	do.	Feldspathic sandstone.....	168	.42	2.4	16.5	17.5	32	64
6630	Archery Station.....	do.	do.	168	.90	2.7	16.7	17.9	9	97
6657	Summit Station.....	do.	Sandstone.....	162	.80	6.7	6.0	17.9	6	26
6721	Roeders Station.....	do.	do.	162	.75	6.4	6.2	18.0	6	(1)
7179	do.	do.	Feldspathic sandstone.....	168	.77	2.7	14.9	15.0	11	96
7310	Port Clinton.....	do.	Quartzite.....	162	.41	2.2	18.6	19.3	20	14
4814	Roeders Station.....	do.	Slate.....	172	.41	4.0	10.0	12.3	28	69
6556	Somersfield.....	Somerset.	Limestone.....	168	.64	3.4	11.8	15.7	14	105
2036	do.	do.	do.	168	.53	4.3	9.3	14.0	6	65
2052	do.	do.	Impure limestone.....	178	1.27	3.5	11.5	16.9	15	193
8925	Boswell.....	do.	Limestone.....	168	1.05	4.4	9.1	17.3	10	12
8926	do.	do.	Argillaceous limestone.....	172	.39	4.9	8.1	17.0	14	15
3243	McSpadden.....	do.	Siliceous sandstone.....	168	.58	2.5	16.0	18.2	11	16
3246	Colley Township.....	Sullivan.	Conglomeratic sandstone.....	165	1.36	7.0	5.7	15.7	8	28
3929	Brooklyn.....	Susquehanna	Sandstone.....	165	1.42	5.0	8.1	13.0	11	25
3930	do.	do.	do.	165	1.47	5.1	7.8	12.3	10	28
4065	do.	do.	do.	165	1.81	4.6	4.6	11.7	8	53
6659	Susquehanna.....	do.	Limestone.....	168	.30	3.8	10.5	13.9	6	127
1516	Mansfield.....	Tioga.	Siliceous limestone.....	168	.36	5.0	8.0	12.5	5	54
2425	Wellsboro.....	do.	Limestone.....	165	1.15	4.7	8.5	16.7	12	35
1883	do.	do.	Sandstone.....	165	1.64	3.0	13.2	12.0	13	108
2827	Duncan Township.....	do.	Calcareous sandstone.....	172	.40	4.2	9.6	16.3	13	34
3061	Delmar.....	do.	do.	168	.78	3.3	12.1	16.3	7	39
3732	Wellsboro.....	do.	Argillaceous sandstone.....	168	.47	5.4	7.4	17.5	25	28
3784	Richmond Township.....	do.	Sandstone.....	165	.38	3.5	11.4	19.0	21	10
3934	Charleston Township.....	do.	Calcareous sandstone.....	168	.86	3.6	11.0	16.3	26	18
3945	do.	do.	Sandstone.....	159	2.81	9.2	9.2	16.3	10	51
4077	do.	do.	Calcareous sandstone.....	168	.43	2.5	15.9	16.5	19	64
1644	Lewisburg.....	Union.	Limestone.....	168	1.23	4.5	9.0	14.7	5	89
2134	do.	do.	do.	168	.81	3.9	10.4	15.7	10	78
2788	do.	do.	do.	168	.73	4.9	8.2	14.8	4	23

5852	Mifflinburg	do.	Argillaceous limestone.	168	.19	5.5	7.2	14.8	8
5853	do.	do.	Limestone.	168	.39	5.3	7.5	13.6	6
2536	Windfield	do.	Slag	184	.47	3.4	11.6	17.7	12
6761	Allenwood	do.	Clay shale	168	1.73	11.8	3.4	0	3
3202	Franklin (near)	Venango	Argillaceous sandstone.	150	4.69	4.5	8.8	(¹)	7
1185	Warren	do.	Feldspathic sandstone.	159	2.73	(¹)	(¹)	(¹)	8
2604	do.	do.	do.	159	2.60	3.6	11.2	5.8	9
2613	Washington	do.	Argillaceous limestone.	168	.73	2.8	14.1	16.5	12
2614	do.	do.	Dolomitic limestone.	175	.95	2.6	15.2	16.8	14
3707	Monongahela	do.	Limestone	172	.24	4.0	10.0	15.8	12
3708	do.	do.	do.	162	3.19	3.3	12.0	16.3	16
2327	Bucklem.	Wayne	Feldspathic sandstone.	165	1.50	3.3	12.0	14.0	8
2370	do.	do.	Ferruginous sandstone.	168	1.30	3.8	10.4	12.5	10
2911	Steen Station (near)	do.	Feldspathic sandstone.	168	1.30	3.8	10.4	12.5	9
5566A	Bucklem.	do.	Conglomeratic sandstone.	156	5.6	2.7	14.6	17.4	4
5566B	do.	do.	do.	175	3.22	11.0	3.6	0	4
5830	Prompton	do.	do.	175	1.21	6.7	5.9	15.3	7
2451	Greensburg	Westmoreland	Feldspathic sandstone.	168	1.22	3.4	11.9	17.8	12
2533	North Huntingdon	do.	Limestone	168	1.01	3.7	10.8	16.9	10
2750	McKeesport (near)	do.	do.	165	1.01	4.9	8.2	17.0	8
2879	Mount Pleasant	do.	do.	172	.96	3.2	12.2	17.0	13
4877	Sewickley Township	do.	do.	168	.57	4.2	9.5	16.9	9
4878	do.	do.	Siliceous limestone.	168	1.24	3.8	10.5	14.1	12
5605	Blairsville-Intersection	do.	Limestone.	172	.36	4.5	8.9	14.3	11
(2)	do.	do.	Siliceous limestone.	168	.41	2.1	19.2	17.2	19
7900	Ligonier	do.	do.	168	.33	2.3	17.5	16.7	8
8911	do.	do.	do.	168	.16	2.6	15.3	17.3	53
1123	West Donegal	do.	Diabase.	187	.26	(¹)	(¹)	18.2	39
1258	Saltsburg	do.	Calcareous sandstone.	165	1.64	3.6	11.0	9.9	11
2055	Loyalhanna Township	do.	Feldspathic sandstone.	159	2.91	2.7	14.8	13.3	9
1873	Nicholson	do.	do.	168	1.49	3.8	10.6	16.0	10
3191	Scranton	Wyoming	Sandstone.	162	.66	3.7	10.9	19.0	9
5388	Black Walnut	do.	do.	165	1.33	4.8	8.4	14.6	12
1299	Marsh Run Township	York	Gabbro	184	.34	3.2	18.5	17.5	14
2100	(2)	do.	do.	187	.91	2.2	12.4	17.7	12
3410	York Haven	do.	do.	190	.34	2.6	15.6	18.3	15
1366	York	do.	Diabase.	190	.10	2.0	19.8	(¹)	15
1694	Carroll Township	do.	do.	187	.45	1.8	21.7	18.3	22
1696	Warrington Township	do.	do.	193	.07	2.5	15.9	18.5	16
2937	Dillsburg (near)	do.	do.	187	.41	2.2	17.9	19.1	26
7458	York	do.	do.	187	.89	3.9	10.3	18.8	22
1691	do.	do.	Micaceous sandstone.	172	.33	3.6	11.2	13.9	14
1695	Warrington Township	do.	Indurated sandstone.	175	.63	2.4	16.4	18.7	15
1948	Hanover	do.	Sandstone.	143	4.62	12.8	3.1	3.1	(¹)
2936	Dillsburg (near)	do.	Feldspathic sandstone.	150	4.32	6.5	6.2	16.6	10
2938	do.	do.	Ferruginous sandstone.	147	4.46	13.4	3.0	11.0	8
1866	Hanover	do.	Quartzite.	165	.20	2.6	13.9	19.3	6
7330	York	do.	do.	159	.94	3.6	11.1	18.7	9
9666	do.	do.	do.	162	.68	4.1	9.8	19.3	22
2135	Wellsville Borough	do.	Epidoste.	178	.67	2.8	14.3	18.9	9
2562	Washington Township	do.	Hematite.	256	4.36	18.3	2.2	17.6	11
2762	Spring Forge	do.	Limestone.	178	.37	3.2	12.5	(¹)	26

Test not made.

Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916—Contd.

PENNSYLVANIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
2948	York.....	York.....	Limestone.....	Pounds. 172	Pounds. 32	4.5	8.9	14.0	5	53
4706	York (near).....	do.....	do.....	168	19	5.8	6.8	8.8	6	24
5780	do.....	do.....	do.....	168	48	4.3	9.3	14.3	3	36
5781	West York.....	do.....	Argillaceous limestone.....	175	29	2.8	14.2	17.3	28	35
5782	Hellam.....	do.....	Crystalline limestone.....	172	18	3.1	13.1	16.7	7	41
5783	York.....	do.....	do.....	172	19	3.1	12.9	14.8	9	18
5784	do.....	do.....	do.....	168	44	4.8	8.3	14.8	7	36
7009	do.....	do.....	Limestone.....	178	22	3.9	10.3	17.1	6	23
7050	do.....	do.....	do.....	172	15	5.7	7.0	9.0	4	20
7056	do.....	do.....	do.....	175	30	6.1	6.5	15.6	5	60
4007	Glen Rock.....	do.....	Crystalline limestone.....	181	30	6.8	5.9	12.3	6	31
4008	Farm Grove.....	do.....	Chlorite epidiorite schist.....	193	37	2.8	14.3	18.4	3	23
5706	Ermsville.....	do.....	Hornblende chlorite schist.....	175	15	4.3	8.6	14.3	16	30
5778	Wrightsville.....	do.....	Dolomitic marble.....	172	14	2.0	15.3	17.1	7	39
5785	York.....	do.....	do.....	178	19	2.3	11.8	15.3	13	30
7458	do.....	do.....	do.....	168	49	4.3	9.3	15.8	9	70
7457	Hanover.....	do.....	Siliceous marble.....	178	48	8.2	4.9	15.9	7	44
9057	York.....	do.....	Dolomitic marble.....	178	16	4.0	10.0	17.7	12	28
7780	Hanover.....	do.....	Siliceous dolomite.....	175	19	4.7	8.5	13.9	11	34
7408	Blue Mountain.....	().....	Serpentine.....	169	31	5.0	7.9	16.3	5	54
7451	().....	().....	Carbonaceous limestone.....	168	31	5.0	7.9	16.3	5	54

RHODE ISLAND.

886	Bristol.....	Bristol.....	Chloritic quartzite.....	172	0.45	4.7	8.5	18.9	10	22
889	do.....	do.....	Gneissoid granite.....	168	28	2.8	14.3	18.0	10	53
890	Warren.....	do.....	Chloritic sandstone.....	168	38	2.7	15.0	15.3	24	12
891	East Greenwich.....	Kent.....	Blotite gneiss.....	168	15	2.6	15.1	18.8	20	59
1818	Warwick.....	do.....	Mica schist.....	165	74	3.8	10.6	17.5	6	9
1821	do.....	do.....	Mica quartzite.....	172	59	3.9	10.4	18.7	4	27
302	Middletown.....	Newport.....	Quartzite.....	(²)	(²)	3.1	12.8	(²)	(²)	(²)
886	do.....	do.....	do.....	175	27	2.8	14.4	10.2	15	12
1019	Newport.....	do.....	Granite.....	162	59	3.0	13.5	18.7	15	53
1020	Portsmouth.....	do.....	Arkose gneiss.....	181	25	4.2	9.6	15.4	10	37
1817	Jamestown.....	do.....	Metamorphic sandstone.....	168	59	4.8	8.3	18.3	16	13
1822	Portsmouth.....	do.....	Feldspathic sandstone.....	168	59	2.4	16.8	16.7	15	15
14	Cumberland.....	Providence.....	Peridotite.....	225	(²)	4.2	9.4	(²)	(²)	(²)

1022	do.	Altered peridotite.	221	.27	4.3	9.3	15.0	12	30
42	do.	Quartzite.	(2)	(2)	4.4	9.1	(2)	(2)	(2)
888	North Providence.	Mica quartzite.	172	.40	2.6	15.5	16.5	21	25
894	Craston.	Feldspathic quartzite.	172	.06	3.2	12.5	17.6	(2)	33
1018	Cumberland.	Quartzite breccia.	162	.69	2.9	14.0	(2)	(2)	13
5589	do.	Quartzite.	162	.47	4.4	9.0	19.3	16	5
659	Providence.	Augite diorite.	187	.18	1.9	20.6	(2)	(2)	23
887	Craston.	Granite.	175	.19	3.4	11.9	19.1	10	39
893	Johnston.	Gneissoid granite.	165	.25	2.2	18.2	18.5	12	12
895	Smithfield.	Granite.	162	.19	3.7	10.8	(2)	10	18
1017	Cumberland.	Hornblende granite.	175	.26	1.6	25.6	17.9	12	29
9242	Smithfield.	Gneissoid granite.	165	.45	3.0	13.3	18.3	6	30
892	East Providence.	Indurated sandstone.	168	.31	3.0	13.4	19.1	7	9
897	Johnston.	Amphibolite.	193	.17	2.8	14.2	19.0	9	11
6827	do.	do.	187	.38	1.8	21.7	18.6	26	13
1819	do.	Hornblende schist.	184	.75	3.0	13.2	18.3	8	32
1820	East Providence.	Chlorite gneiss.	175	.46	4.6	8.6	15.7	9	17
5023	Craston.	Serfite gneiss.	165	.31	4.6	8.6	17.8	9	26
1021	Westerly.	Granite.	165	.65	2.4	16.6	17.7	12	25
1213	South Kingston.	do.	162	.43	5.2	7.7	15.8	4	11
1259	Westerly.	do.	165	.31	2.8	14.1	18.1	11	15
1260	do.	do.	165	.52	2.2	18.5	18.2	9	22
8807	do.	do.	165	(2)	4.0	10.0	(2)	6	(2)
8808	do.	do.	165	(2)	2.9	13.8	(2)	12	(2)
8809	do.	do.	165	(2)	3.5	11.6	(2)	11	(2)

SOUTH CAROLINA.

783	Abbeville.	Chert.	162	1.19	22.1	1.8	(2)	(2)	11
3451	do.	do.	165	.35	9.1	4.4	(2)	(2)	6
6490	do.	Muscovite granite.	165	.57	4.5	8.8	17.2	9	14
6491	do.	Altered muscovite granite.	159	.22	18.2	2.2	0.0	3	24
6493	do.	Gneissoid granite.	165	.32	3.8	10.5	18.0	6	32
6492	do.	Granite gneiss.	175	.64	13.2	3.0	14.1	6	49
2545	do.	Ferruginous sandstone.	200	5.09	10.3	3.9	(2)	(2)	26
8389	Anderson.	Granite.	165	.60	5.3	7.5	18.3	6	34
1758	do.	Lanesione.	165	.11	5.7	7.0	18.7	9	14
2386	Charlee.	Granite.	173	.28	3.2	12.7	18.9	8	19
5505	Farfield.	do.	165	.18	2.6	13.2	18.3	14	12
5508-1	do.	do.	(1)	(2)	(2)	(2)	18.5	11	(2)
3893	do.	Biotite granite.	165	.22	5.0	8.1	18.2	9	4
4725	Greenville.	Granite.	172	.33	5.1	7.9	(2)	(2)	15
3759	do.	Gneissoid granite.	165	.31	3.1	12.8	18.9	10	13
1449	Laurens.	Altered rhyolite.	168	.51	2.4	16.7	18.8	21	16
2024	Lexington.	Gneissoid granite.	162	.81	5.5	7.3	17.1	5	79
3923	Oconee.	Marble.	178	.28	5.5	7.2	17.7	6	21
3923	Beverly.	Granite gneiss.	162	.28	5.5	7.2	17.7	13	21
4008	Pickens.	Granite.	168	.47	3.5	11.4	17.8	13	18
374	do.	do.	165	.17	2.9	13.9	(2)	(2)	(2)
374	Columbia.	Richland.	165	.17	2.9	13.9	(2)	(2)	(2)

¹ Exact locality not known.² Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

SOUTH CAROLINA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
375	Pacolet.....	Spartanburg	Granite.....	165	Pounds.	1.9	20.9	(1)	(1)	(1)
193	Spartanburg.....		do.....	172	48	2.1	19.2	18.2	10	20
193	Pacolet.....		do.....	165	33	4.1	9.8	17.7	15	14
1079	Spartanburg.....		Syenite.....	168	40	2.4	16.9	18.4	20	20
210	do.....		Biotite gneiss.....	175	25	3.8	10.6	15.6	7	28
1217	Union.....		Granite.....	168	27	5.6	7.1	17.2	9	20

SOUTH DAKOTA.

2106	Lead.....	Lawrence	Altered diorite.....	168	0.28	2.2	17.9	17.3	15	67
2107	do.....		Granite porphyry.....	162	73	2.9	14.0	17.5	10	95
2108	do.....		Altered rhyolite.....	167	4.50	3.8	10.7	15.8	16	500+
3372	do.....		Limestone.....	168	21	5.6	7.3	15.6	5	61
3373	do.....		Sandstone.....	162	44	5.2	12.2	19.0	10	0
3374	do.....		Dolomite.....	172	1.03	5.2	7.7	16.3	9	22
3375	do.....		Weathered chert.....	130	4.05	2.2	12.3	(1)	(1)	500+
449	Rewena.....		Quartzite.....	163	13	2.8	14.2	14.4	4	35
5582	Minnehaha.....		Marble.....	168	14	4.0	10.0	16.8	4	24
5584	Rapid City.....		Dolomite.....	162	1.84	4.2	9.0	16.8	4	24
5672	do.....		Feldspathic quartzite.....	168	21	2.4	16.7	19.0	25	24

TENNESSEE.

2104	Clinton.....	Anderson	Feldspathic limestone.....	165	0.84	2.7	14.9	16.5	11	76
2367	Camden.....		Chert.....	140	2.63	(1)	(1)	19.2	9	36
4333	Elizabethton.....		Argillaceous limestone.....	172	25	3.3	12.1	19.2	18	31
5597	Quarry.....		Limestone.....	168	34	4.4	9.1	17.7	9	64
9223	Watauga Point.....		Dolomite.....	178	26	4.1	9.8	(1)	9	17
1325	Cumberland Gap.....		Limestone.....	172	24	3.9	10.2	15.8	10	76
1326	do.....		do.....	168	31	3.8	10.4	(1)	(1)	39
376	Nashville.....		do.....	168	15	5.0	8.0	(1)	(1)	(1)
377	do.....		do.....	168	20	5.2	7.7	(1)	(1)	(1)
378	do.....		do.....	168	1.87	5.8	6.7	(1)	(1)	(1)
379	do.....		do.....	153	3.08	15.1	2.6	(1)	(1)	(1)
6557	do.....		do.....	168	.90	3.5	11.3	10.4	6	80

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

TEXAS.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
1199	San Antonio.	Bexar.	Limestone.	Pounds. 153	Pounds. 4.89	(1) (1)	(1) (1)	0		42
1202	do.	do.	do.	143	8.29			0		21
1229	do.	do.	do.	159	2.19	5.2	7.8	7.1		3
1500	Sand Pitt Station.	Burleson.	Sandstone.	140	3.50	4.2	9.6	16.7		4
7609	New Braunfels.	Comal.	Limestone.	165	1.12	4.8	8.3	13.2		13
2084	El Paso.	El Paso.	Syenite.	159	1.58	14.4	15.7	18.2		12
3727	do.	do.	do.	159	1.40	4.1	9.9	18.2		200
2185	do.	do.	Syenite porphyry.	159	1.68	2.5	15.7	18.2		150
7297	Dublin.	Grayson.	Fossiliferous limestone.	168	.64	6.7	6.0	14.6		257
1479	Denison.	do.	Limestone.	159	2.77	5.2	7.7	12.8		61
1480	do.	do.	do.	162	1.94	4.4	9.2	15.4		107
3414	Denison (near)	do.	do.	162	2.20	(1)	(1)	15.9		81
3412	do.	do.	Ferruginous limestone.	153	5.65	(1)	(1)	12.3		23
3413	do.	do.	do.	159	2.71	(1)	(1)	15.6		101
5642	Denison.	do.	Argillaceous limestone.	162	2.12	5.7	7.0	13.7		74
5832	do.	do.	do.	159	3.65	6.6	6.6	14.6		44
5831	do.	do.	do.	159	3.65	7.1	5.6	14.8		41
5709	Sherman.	do.	Altered granite.	162	.61	4.8	8.3	19.3		41
5938	do.	do.	Argillaceous limestone.	134	11.96	61	5.3	0		83
1938	Marshall.	Harrison.	Ferruginous limestone.	153	.52	22.9	1.7	2.7		82
2685	Hillsboro.	Hill.	Limestone.	143	8.60	9.5	4.2	176		176
3869	do.	do.	do.	165	1.94	5.0	8.0	(1)		39
4412	Bridgeport.	Jack.	do.	168	1.34	5.5	7.3	14.3		52
5305	Stevartown.	do.	do.	168	.82	4.9	8.2	14.8		50
7331	Jackshoro.	do.	do.	165	1.63	5.2	7.7	13.5		32
7332	do.	do.	do.	165	1.27	3.8	10.6	14.1		93
6314	Terrell.	Kaufman.	Siliceous limestone.	153	4.11	12.0	3.3	(1)		118
7015	do.	do.	do.	162	1.63	9.0	4.4	14.5		202
7016	Elmo Quarry.	do.	do.	156	2.92	11.3	3.4	5.0		125
3147	Paris.	Lamar.	Sandstone.	143	7.25	0	3.5	4		103
5532	do.	do.	Chert conglomerate.	159	4.49	7.6	8.1	19.4		34
7224	Tehuacana.	Limestone.	Argillaceous limestone.	159	2.28	4.9	5.2	7.8		4
8501	Springfield.	do.	Limestone.	162	1.45	8.9	8.9	15.0		152
8685	Tehuacana.	do.	Fossiliferous limestone.	156	.27	4.0	1.5	4.0		68
6625	Marshall.	Marshall.	Iron conglomerate.	(1)	27	26.0	1.5	(1)		35
5935	Richland.	Navarro.	Crystalline limestone.	165	1.33	6.2	6.5	15.6		152
7070	Corsicana.	do.	Limestone.	168	.60	5.5	7.3	14.1		47

UTAH.

7209	Richland	do.	168	1.02	3.8	10.5	13.3	6	104
5432	Maryneal	do.	139	1.67	6.2	6.5	13.3	4	16
4131	Mineral Wells	Palo Pinto	165	1.22	5.5	1.22	13.5	7	69
6579	Strawn	do.	168	.37	4.2	9.5	18.8	6	44
6396	(2)	do.	162	.33	4.2	9.5	18.8	6	5
6398	(2)	do.	165	.77	4.3	9.3	15.3	6	165
6397	(2)	do.	172	3.31	26.8	9.9	(1)	(1)	11
5455	Ablene	Taylor	165	1.50	4.0	9.9	14.2	7	21
7763	Austin (near)	Travis	199	.21	1.7	23.5	18.7	24	16
8245	(2)	do.	(1)	(1)	(1)	(1)	15.7	5	62
8237	(2)	do.	(1)	(1)	(1)	(1)	15.3	5	36
8238	(2)	do.	(1)	(1)	(1)	(1)	16.0	4	35
8234	(2)	do.	(1)	(1)	(1)	(1)	14.7	5	59
8236	(2)	do.	(1)	(1)	(1)	(1)	16.2	14	33
8239	(2)	do.	(1)	(1)	(1)	(1)	18.7	22	78
7139	Knappa	Uvalde	193	.39	1.8	22.2	17.5	15	67
1499	Grayville Quarry	Washington	143	2.67	5.0	7.9	16.7	12	93
2706	Round Rock	Williamson	156	3.20	10.7	3.8	0	4	23
2707	do.	do.	159	2.64	7.1	5.6	13.2	4	46
2708	do.	do.	153	5.06	23.8	1.7	5.3	3	10
6600	Bridgeport	do.	165	1.03	6.8	5.9	12.2	6	66
6667	do.	do.	168	.36	6.2	6.2	13.8	5	47
6654	(3)	do.	168	.37	6.1	6.6	14.6	6	27
7239	Chico	do.	168	.37	4.3	9.3	14.1	4	61
6633	(2)	do.	168	.26	(1)	(1)	15.6	6	26

8191	(2)	Salt Lake City	165	0.41	7.2	5.6	(1)	(1)	(1)
1995	do.	Morgan	168	.77	2.9	13.7	16.8	12	451
1997	do.	Salt Lake	159	2.31	3.1	12.7	17.9	20	44
3371	(2)	do.	165	.90	4.1	9.8	16.9	11	34
4121	Salt Lake City	do.	206	.69	4.7	8.4	(1)	(1)	5
4122	Sandy City	do.	218	.52	5.6	7.2	(1)	(1)	5
3352	Provo	Utah	168	1.15	5.8	6.9	17.4	6	21
3353	do.	do.	162	1.08	29.2	1.4	(1)	(1)	4
3334	do.	Serpentine schist	175	.16	6.2	6.4	16.2	7	19
3334	do.	Siliceous limestone	162	2.36	3.6	11.0	18.2	20	59
3337	do.	Limestone	165	.45	3.0	13.2	(1)	(1)	10
3338	do.	Sandstone	168	.10	2.3	17.5	19.0	17	28
3359	do.	Bifuminous sandstone	140	1.34	5.2	7.8	5.6	6	500+
4744	do.	do.							

1 Test not made.

2 Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

VERMONT.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				Pounds.	Pounds.					
1946	Middlebury.....	Addison.....	Limestone.....	172	0.62	3.8	10.5	15.4	6	77
1220	North Pownal.....	Bennington.....	Marble.....	168	.36	5.8	7.0	8.9	6	71
1256	do.....	do.....	Limestone.....	172	.30	3.2	12.5	12.6	5	32
2889	Bennington.....	do.....	do.....	168	.41	5.0	8.0	(1)	(1)	53
2884	do.....	do.....	Dolomite.....	178	.35	4.2	9.4	15.0	8	41
2885	do.....	do.....	do.....	178	.33	3.6	11.2	16.6	6	30
2886	do.....	do.....	do.....	178	.34	4.1	9.8	14.5	7	13
2887	do.....	do.....	do.....	175	.98	4.1	9.9	16.9	8	23
2888	do.....	do.....	Quartzite.....	165	.35	2.3	17.2	(1)	(1)	4
7109	do.....	do.....	do.....	165	.29	6.8	5.9	19.2	4	4
6655	Hardwick.....	Caledonia.....	Granite.....	165	.39	4.2	9.5	17.5	6	35
3329	Berlington.....	Chittenden.....	Red dolomitic marble.....	175	.25	3.2	12.3	17.3	23	41
3330	do.....	do.....	Dolomitic marble.....	175	.39	2.5	16.0	16.6	18	31
8369	do.....	do.....	Dolomite.....	175	.42	4.4	9.1	17.2	15	10
8370	do.....	do.....	Dolomite.....	178	.42	3.4	11.7	18.0	11	23
1678	St. Albans.....	Franklin.....	Argillaceous dolomite.....	168	.31	2.8	14.3	19.5	17	4
1681	do.....	do.....	Feldspathic sandstone.....	165	.26	2.3	17.4	19.3	12	3
1680	do.....	do.....	do.....	178	.42	4.2	9.6	16.3	9	9
1726	Swanton.....	do.....	Dolomite.....	172	.20	5.7	7.0	(1)	(1)	26
1679	Isle La Motte.....	Grand Isle.....	Limestone.....	168	.69	4.0	10.1	17.3	9	18
2372	Barton.....	Orleans.....	do.....	181	.09	2.8	14.4	18.5	18	54
2373	do.....	do.....	Biotite hornblende schist.....	165	.28	8.1	5.0	17.7	5	39
726	Wallingford.....	do.....	Biotite granite.....	193	.25	4.7	8.5	(1)	(1)	15
5543	East Wallingford.....	Rutland.....	Amphibolite.....	184	.96	2.6	15.3	17.2	15	111
5950	Rutland.....	do.....	Altered diabase.....	175	.28	3.0	13.2	18.3	10	31
6955	do.....	do.....	Siliceous dolomite.....	165	.15	2.3	17.1	19.2	12	2
1646	Barre.....	do.....	Quartzite.....	165	.65	3.1	12.8	18.7	8	27
3192	do.....	Washington.....	Granite.....	165	.29	4.9	8.2	18.8	9	15
8853	do.....	do.....	Biotite granite.....	165	.44	3.0	13.3	(1)	7	(1)
6677	Bellevue Falls.....	do.....	Granite.....	178	.19	2.9	13.9	14.4	16	50
4092	Hartford.....	Windham.....	Biotite schist.....	181	.41	2.8	14.1	16.9	10	150
4123	Woodstock.....	Windsor.....	Altered diabase.....	187	.06	4.3	9.4	17.2	7	21
		do.....	Hornblende schist.....							

VIRGINIA.

[illegible]

Test not made.

² Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916.—Contd

VIRGINIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
412	Alexandria.	Alexandria.	Mica schist.	Pounds. 175	Pounds. .37	4.3	9.3	(1)	(1)	(1)
1310	Chain Bridge.	do.	do.	175	.30	4.8	8.4	17.1	6	31
1320	(2)	do.	do.	175	.24	4.2	9.6	(1)	(1)	29
1440	(2)	do.	Quartz.	165	.12	3.7	10.8	(1)	30	0
1441	(2)	do.	Granite.	172	.27	2.6	15.6	18.0	11	40
5952	Rosslyn.	do.	Altered granite.	175	.26	2.9	13.6	17.8	(1)	22
1657	(2)	do.	Granite gneiss.	172	.35	4.7	9.5	(1)	6	28
5953	Covington (near).	Alleghany.	Crystalline limestone.	165	.64	4.2	8.5	14.1	(1)	43
9453	Clifton Forge.	do.	Feldspathic sandstone.	168	1.04	(1)	(1)	15.8	20	74
1889	Amherst (1 mile south of).	Amherst.	Quartzite.	165	.05	4.3	9.3	(1)	(1)	2
1900	Sweet Briar Station (near).	do.	Micaceous hornblende schist.	187	.15	5.7	7.1	(1)	5	53
1901	(2)	do.	Hornblende schist.	187	.23	3.3	12.1	14.0	10	21
1976	Melvor Station.	do.	do.	190	.44	6.3	6.4	15.7	10	37
1984	Lynchburg Road.	do.	do.	193	.37	2.7	15.0	17.0	10	12
2208	(2)	do.	Mica schist.	165	.82	4.4	9.0	16.2	7	12
2221	Lynchburg (near).	do.	Hornblende schist.	190	.33	5.5	7.3	16.9	8	22
2679	(2)	do.	do.	193	.30	4.2	9.5	17.7	9	13
2831	(2)	do.	do.	184	.88	12.8	3.1	16.2	6	24
3098	(2)	do.	do.	193	.21	3.0	13.2	17.9	8	15
4102	Monroe.	do.	do.	193	.26	3.1	12.7	16.3	10	13
4119	do.	do.	do.	193	.23	5.9	6.8	14.2	9	20
4861	Amherst Courthouse.	do.	Mica schist.	168	.21	8.2	4.9	18.3	10	18
4862	do.	do.	Hornblende biotite schist.	187	.25	6.2	6.5	16.0	7	10
1972	Amherst Depot.	do.	Epidosite.	190	.61	7.4	5.4	19.3	23	10
1973	Amherst Depot (near).	do.	do.	206	1.10	(1)	(1)	10.7	10	44
1978	Monroe.	do.	Biotite gneiss.	172	.48	4.7	8.5	16.5	9	58
1982	(2)	do.	do.	172	.68	(1)	(1)	16.7	6	38
3381	James River.	do.	Diorite gneiss.	184	1.19	5.7	7.0	9.0	6	52
3521	(2)	do.	Hornblende gneiss.	187	.59	16.4	2.4	12.3	5	13
4201	Monroe.	do.	Biotite gneiss.	172	.28	9.2	4.3	17.0	6	28
4203	(2)	do.	do.	162	.55	7.2	5.6	18.2	5	29
4204	do.	do.	do.	172	.60	7.4	5.9	17.8	5	25
4389	do.	do.	Gneiss.	172	.63	5.3	7.5	15.7	7	20
4860	Amherst Courthouse.	do.	Biotite gneiss.	193	.33	6.3	7.9	14.6	8	14
4863	do.	do.	do.	175	.25	5.3	7.3	17.6	11	13
4937	do.	do.	do.	173	.41	6.6	6.0	16.8	12	8
6823	Amherst Courthouse (near).	do.	Granite gneiss.	173	.73	8.7	4.0	9.2	3	43
6823	(2)	do.	Biotite gneiss.	171	.69	7.0	5.1	13.7	5	56
2223	(2)	do.	Amphibolite.	187	1.04	10.3	3.9	13.5	7	75

3019	(2)	do.	Altered diabase	190	.21	1.8	22.0	18.6	24	11
6824	(2)	do.	Altered diorite	190	.88	2.4	16.8	17.9	8	48
7051	Clifford	do.	Gneissoid granite	168	.29	5.3	7.5	17.7	4	16
7891	Madison Heights	do.	Altered biotite granite	175	.30	4.7	8.4	18.0	8	40
2057	Appomattox	do.	Sandstone	162	1.07	(1)	(1)	16.5	9	17
5926	Basie	Augusta	Quartzite	165	.27	4.6	8.6	(1)	(1)	4
1904	Staubton (near)	do.	Dolomitic limestone	175	1.19	4.5	8.9	15.0	8	68
2087	Staubton (1 mile north of)	do.	Limestone	168	1.98	3.4	11.8	15.5	11	37
2680	Craigsville	do.	do.	168	.32	3.8	10.6	17.7	9	26
2999	Fordwick (near)	do.	do.	168	.27	4.6	8.8	15.7	7	48
5384	Brookwood	do.	do.	172	.41	(1)	(1)	16.0	41	7
5476	Waynesboro	do.	do.	178	.22	5.4	7.4	15.4	5	23
5620	Staubton	do.	do.	178	.22	5.1	7.8	18.3	19	20
2997	Fordwick (near)	do.	Gneiss	165	.08	3.9	10.3	15.3	6	31
2938	do.	do.	Dolomite	172	.63	4.7	8.5	15.5	7	18
4798	Staubton	do.	Dolomite	178	.68	3.2	12.7	13.2	11	13
5353	Brookwood	do.	do.	175	.66	3.1	12.8	16.5	16	23
3095	(2)	do.	Chlorite schist	187	.37	3.7	10.8	16.8	8	44
3101	Basie (near)	do.	Sandstone	168	.37	2.9	13.7	16.1	22	34
3724	Waynesboro	do.	do.	168	2.29	4.7	8.5	16.8	6	186
5437	Waynesboro	do.	do.	168	1.08	7.9	5.1	19.0	6	6
8741	(2)	do.	Slate	172	.42	12.4	3.2	6.3	4	29
1968	Boonsboro	do.	Calcareous slate	168	.65	4.6	8.8	11.8	10	32
2912	Bedford	do.	Altered diabase	172	.39	3.8	10.6	13.2	9	20
4678	do.	do.	Biotite gneiss	162	1.16	8.8	4.6	10.8	2	76
8804	Albert	do.	Granite gneiss	175	.40	11.1	3.6	15.8	6	29
1969	Lynchburg	do.	do.	172	.38	4.4	9.1	17.8	7	28
2913	(2)	do.	Hornblende epidote schist	175	1.26	5.2	7.7	18.8	9	23
3088	Lynchburg (near)	do.	Hornblende schist	184	.79	8.6	4.7	12.3	(1)	8
8021	Holcomb Rock	do.	Biotite schist	178	.46	7.3	5.5	16.7	(1)	8
2756	Gala	do.	Snatter slag	187	1.50	10.2	3.9	(1)	(1)	4
2757	do.	do.	Quartzite	162	.71	3.2	12.3	(1)	(1)	7
2050	Borecourt	do.	Pink quartzite	165	.19	7.5	5.3	16.5	(1)	4
3326	Campbell	do.	Granite	165	.51	29	3.7	10.8	6	28
2162	Alta Vista	do.	do.	162	.29	20	10.8	18.7	10	8
2601	Lynchburg	do.	Quartzite	165	.20	2.6	15.5	19.0	14	10
2602	(2)	do.	Limestone	168	.51	5.7	7.0	14.3	4	56
2718	Lynchburg (near)	do.	do.	168	.15	4.2	9.5	17.1	5	47
2905	(2)	do.	Hornblende schist	190	.49	4.4	9.0	15.2	8	15
5715	Alta Vista	do.	Quartz schist	168	.18	3.9	10.3	(1)	(1)	15
6590	do.	do.	Biotite schist	168	.17	3.3	12.0	18.3	17	21
8821	(2)	do.	Quartz mica schist	168	.41	3.3	12.0	17.7	18	21
3327	Alta Vista	do.	Muscovite schist	172	.41	4.6	8.8	14.3	8	21
5050	Lynchburg	do.	Mica gneiss	172	.37	2.3	17.1	18.0	18	15
4619	(2)	do.	Serpentine gneiss	168	.37	3.3	12.0	18.7	6	6
3275	Randolph	do.	Calcareous sandstone	172	2.81	4.2	9.4	13.6	9	22
3276	do.	do.	Altered diorite	181	.50	2.5	14.5	18.8	26	21
			Hornblende granite	162	1.61	4.0	9.9	18.6	9	62

* Exact locality not known.

† Test not made.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916—Contd.*

VIRGINIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
1393	Norfolk.....	Chesterfield	Granite.....	Pounds. 165	Pounds. 44	2.5	16.1	(1)	(1)	88
1774	Richmond (near).....	do.	do.	165	31	3.2	12.3	17.5	11	33
3224	(?)	do.	do.	165	23	2.1	19.0	18.6	13	20
7386	Berryville.....	Clark	Argillaceous limestone.....	172	16	2.5	16.0	17.4	13	30
2932	Grassville.....	Craig	Dolomitic limestone.....	168	31	4.1	9.7	(1)	(1)	22
2282	Stevensburg (near).....	Culpeper	Metamorphic sandstone.....	172	1.07	2.2	18.0	19.3	20	25
2282	Monk Run Mill (near).....	do.	do.	168	1.38	2.3	17.7	19.1	14	98
2283	Kellyville (near).....	do.	do.	172	1.67	2.6	15.6	18.8	60	57
2324	Brandy Station.....	do.	do.	173	2.77	2.4	16.7	18.3	30	344
2325	Culpeper (near).....	do.	do.	159	3.04	3.1	17.2	16.8	19	130
3862	(?)	do.	Ferruginous sandstone.....	175	33	3.1	12.9	17.8	24	27
6258	(?)	do.	Argillaceous sandstone.....	168	61	2.3	17.4	16.3	32	27
6258	(?)	do.	Indurated argillaceous sandstone.....	153	4.62	4.6	8.6	12.3	9	195
7003	Culpeper (near).....	do.	Argillaceous sandstone.....	162	2.51	4.7	8.5	14.7	12	47
2324	do.	do.	Amphibolite.....	190	1.18	2.8	13.5	16.6	21	235
2324	do.	do.	do.	181	1.65	2.1	19.3	17.8	11	92
7315	Culpeper.....	do.	do.	187	92	4.6	8.7	17.5	18	112
8433	Griffinsburg.....	do.	do.	193	44	2.3	17.2	17.7	16	26
8619	do.	do.	do.	193	46	1.5	26.6	18.5	36	36
3520	Culpeper (near).....	do.	do.	196	85	2.8	14.1	18.3	6	22
3731	Stevensburg Township.....	do.	Altered diabase.....	184	85	3.3	18.4	18.4	24	49
3867	(?)	do.	Hypersilene diabase.....	170	97	3.7	12.9	18.0	11	20
4816	Brandy Station (near).....	do.	Slate.....	173	32	2.8	10.8	18.0	32	20
4817	Carico Mill (near).....	do.	do.	173	32	(1)	14.3	16.8	26	30
3937	Brandy Station.....	do.	do.	173	32	(1)	(1)	17.8	20	14
4089	Buena.....	do.	Chert.....	173	32	2.8	14.4	17.8	32	32
5878	Culpeper.....	do.	Gabbro.....	193	47	(1)	(1)	18.9	11	12
5879	do.	do.	Altered basalt.....	187	23	3.0	13.3	18.2	47	41
7168	Culpeper (3 miles northeast of).....	do.	do.	178	1.23	2.8	14.3	18.5	20	31
6543	(?)	do.	Altered basalt breccia.....	187	41	4.0	10.1	11.9	5	85
6544	(?)	do.	Biotite schist.....	173	16	3.8	10.5	13.2	9	72
8320	Culpeper (9 miles from).....	do.	do.	168	37	4.6	8.6	14.2	9	50
6545	(?)	do.	Sericite schist.....	171	60	5.9	6.8	18.5	4	51
8318	Boston (near).....	do.	Mica gneiss.....	168	63	8.9	4.5	13.1	7	73
8319	Hazel River Bridge (near).....	do.	Micaceous quartzite.....	165	39	4.6	8.7	18.7	11	22
8432	Griffinsburg.....	do.	Biotite gneiss.....	168	25	2.9	14.0	18.2	5	34
8618	do.	do.	Granite gneiss.....	165	43	4.7	9.8	18.0	5	27
6796	(?)	Dinwiddie	Granite.....	165	23	4.1	8.4	18.5	5	26

	Fairfax.	Limestone.	168	.47	(1)	(1)	15.8	6	57
1196	Fairfax Courthouse.....	do.....	168	.20	(1)	(1)	13.2	6	24
1197	do.....	do.....	168	.73	(1)	(1)	18.2	(1)	93
1198	do.....	Granite gneiss.....	168	.31	(1)	15.6	(1)	14	30
1318	Fredericksburg.....	Sericite gneiss.....	172	.23	3.5	2.1	18.8	11	17
3017	Ocoquan.....	Granite gneiss.....	168	.45	4.3	9.3	18.2	8	24
4397	(2).....	Sericite gneiss.....	168	1.00	9.0	4.5	15.7	11	48
5010	(2).....	Biotite gneiss.....	175	.39	4.1	9.7	19.0	11	26
5011	(2).....	Muscovite gneiss.....	165	.88	10.5	3.8	16.0	7	29
5012	(2).....	Biotite gneiss.....	178	.17	4.0	10.0	17.8	12	26
5014	(2).....	Sericite gneiss.....	168	.45	2.2	13.3	18.5	17	112
7317	Ocoquan.....	Granite gneiss.....	175	.38	4.4	10.8	18.5	4	28
8226	McLean.....	Diabase.....	168	.19	(1)	(1)	18.7	19	45
1954	Herdon.....	do.....	184	.50	3.0	13.3	18.0	14	146
6315	Clifton Station.....	do.....	184	.37	2.5	15.7	17.4	15	115
7187	Clifton.....	do.....	184	.87	3.7	10.9	16.0	4	171
7258	(2).....	Altered diabase.....	175	1.88	7.8	17.4	17.4	11	500+
2000	Herdon.....	Feldspathic sandstone.....	166	2.45	5.1	12.0	18.9	13	68
3445	Falls Church.....	Muscovite granite.....	165	.63	2.9	13.6	18.4	15	21
4958	Falls Church (near).....	Biotite granite.....	175	.13	3.3	7.2	17.8	13	29
5005	Falls Church.....	Gneissoid granite.....	165	1.42	5.5	7.9	18.7	8	33
5013	(2).....	Biotite granite.....	172	.34	5.1	10.8	16.3	10	31
4173	(2).....	Epidiosite.....	187	.53	3.7	7.8	17.4	7	21
5371	Fairfax Courthouse (near).....	Altered diorite.....	178	.29	5.1	8.2	15.8	11	56
6043	Fairfax.....	Serpentine.....	175	1.14	4.9	4.9	17.4	13	12
8779	Vienna.....	Epidote chlorite schist.....	168	.65	8.1	21.7	17.4	(1)	(1)
782	Fauquier.....	Diabase.....	187	.14	1.8	18.7	18.6	24	41
5762	Warrenton.....	Altered diabase.....	187	.45	2.1	(1)	17.3	6	61
6603	do.....	do.....	187	(1)	(1)	(1)	18.7	38	41
8305	Delaplane.....	Quartzite.....	165	.32	2.3	17.4	(1)	(1)	4
1607	Broad Run.....	do.....	165	2.95	3.1	13.1	(1)	(1)	2
4617	do.....	Micaceous quartzite.....	163	.50	2.6	13.4	(1)	(1)	3
4900A	do.....	Quartz.....	168	1.37	1.0	10.6	19.5	7	255
1785	Beaton (1 mile east of).....	Slate.....	168	1.37	3.8	11.7	11.7	10	207
1786	Remington (3 miles east of).....	do.....	168	1.29	2.2	18.5	16.0	21	239
2414	The Plains (1½ miles north of).....	Epidiosite.....	187	.59	2.0	19.6	18.0	22	3
4900B	Broad Run.....	do.....	200	.26	(1)	(1)	19.0	8	9
5639	Warrenton.....	do.....	181	.56	4.0	10.0	(1)	(1)	16
5640	do.....	do.....	193	1.05	3.3	12.0	18.7	73	73
5641	do.....	do.....	187	1.65	3.6	11.2	19.3	11	18
2415	The Plains (4 miles north of).....	Schist.....	168	.63	5.4	7.4	17.8	16	22
2935	(2).....	Epidote chlorite schist.....	190	1.14	2.8	14.2	16.8	20	21
3132	The Plains.....	Hornblende epidote schist.....	190	1.28	8.8	4.6	17.9	20	152
3499	(2).....	Hornblende schist.....	190	.34	4.6	8.7	15.2	9	24
2416	The Plains (4½ miles north of).....	Gneiss.....	168	.47	4.1	9.8	18.7	7	20
3084	(2).....	Sericite gneiss.....	165	.35	3.4	11.7	18.8	9	15
3343	(2).....	Gneiss.....	172	.28	6.0	6.7	17.3	10	34
4175	Catlett.....	Gabbro.....	187	.34	1.8	22.2	18.5	20	48
8304	Delaplane.....	Hornblende granite.....	165	.98	7.9	5.1	19.5	4	64
4900C	Broad Run (near).....	Sandstone.....	165	.14	(1)	(1)	19.0	11	(1)
5923	Strathmore.....	Chlorite epidote schist.....	175	.36	5.0	8.0	16.1	6	23
6465	(2).....	Sericite chlorite schist.....	172	.43	4.1	9.8	13.0	9	17

1 Test not made.

2 Exact locality not known.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916*—Contd.

VIRGINIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				<i>Pounds.</i>	<i>Pounds.</i>					
5678	Eggleston (near).....	Giles.....	Dolomite.....	178	.44	4.4	9.2	16.0	24	27
5978	Pembroke.....	do.....	Dolomitic marble.....	178	.27	3.1	12.8	14.7	11	15
1317	Bosobel.....	Goochland.....	Granite gneiss.....	165	.30	4.0	9.9	18.6	(1)	61
1857	Penitentiary Farm.....	do.....	Gneiss.....	168	.30	3.1	13.1	17.6	9	20
1858	(2).....	do.....	Biotite gneiss.....	162	.58	6.7	5.9	18.0	8	56
1859	(2).....	do.....	Granite gneiss.....	165	.26	4.0	10.0	18.2	9	110
3240	(2).....	do.....	do.....	165	.21	3.5	11.4	19.0	12	52
5924	Bosobel.....	do.....	do.....	162	.28	4.5	9.0	19.3	8	50
8712	(2).....	do.....	Granite.....	162	.52	4.8	8.3	18.7	15	38
4778	Emporia.....	Greensville.....	do.....	168	.19	2.5	15.7	18.7	10	25
3468	Emporia (near).....	do.....	Granite gneiss.....	181	.38	3.5	11.4	17.8	9	39
3036	Virginia.....	Halifax.....	Altered andesite.....	172	.15	3.3	12.2	(1)	(1)	19
3172	do.....	do.....	Epidote chlorite schist.....	168	.18	3.7	10.9	19.0	10	15
1878	Verdow Station (near).....	Hanover.....	Granite.....	168	.44	2.8	14.3	2.8	8	22
1823	Richmond.....	Henrico.....	do.....	165	.54	4.1	9.7	17.8	11	16
3933	do.....	do.....	Biotite granite.....	165	.21	3.1	13.0	18.8	7	10
8747	do.....	do.....	Granite.....	162	.62	2.3	4.4	19.0	8	22
8942	do.....	do.....	Aplite granite.....	165	.53	4.3	17.4	18.2	7	10
3266	(2).....	do.....	Hornblende epidote schist.....	190	.76	2.5	16.1	18.0	9	50
2863-1	do.....	Lee.....	Limestone.....	168	.48	4.0	10.0	16.5	10	49
2864-2	do.....	do.....	do.....	168	.07	4.8	8.3	16.0	6	25
1011	Paeonian Springs.....	do.....	Gneiss.....	168	.43	5.7	7.0	18.0	14	52
1012	do.....	Loudon.....	Epidote.....	172	.45	3.6	11.2	19.1	14	83
1322	Mount Weather.....	do.....	Hornblende schist.....	187	.87	2.9	14.0	13.1	13	71
3817	Paeonian Springs.....	do.....	do.....	187	.75	3.4	11.7	19.0	26	19
1991	Belmont Park.....	do.....	Gabbroitic diabase.....	187	.92	2.8	14.4	18.5	16	57
1690	Belmont Park (near).....	do.....	Diabase.....	187	.35	3.1	12.8	18.2	14	17
9047	Belmont Park.....	do.....	do.....	187	.43	2.6	15.5	18.3	13	22
3493	Broad Run.....	do.....	Gabbro.....	187	.21	2.8	14.4	18.6	19	26
7832	(2).....	do.....	Cherty limestone.....	168	.47	5.3	7.5	13.2	6	46
4826	do.....	do.....	Quartzite.....	165	.17	8.1	11.3	19.3	21	2
871	Mineral.....	Louisa.....	Chlorite gneiss.....	187	.16	8.1	4.9	(1)	(1)	87
3265	(2).....	Lunenburg.....	Epidote quartzite.....	168	.76	2.7	14.9	18.2	10	6
5716	Kenbridge.....	do.....	Gneissoid quartzite.....	162	.15	3.1	12.8	19.1	8	17
3150	Chase City.....	do.....	Serpentine schist.....	168	.73	8.5	4.7	12.4	10	15
3149	do.....	Mecklenburg.....	Epidote schist.....	184	.57	3.5	11.5	14.5	12	16
3176	do.....	do.....	Biotite schist.....	168	.85	4.2	9.5	16.3	9	66
7819	Clarksville.....	do.....	Mica schist.....	165	1.01	3.3	12.3	10.2	9	17
(2).....	do.....	do.....	Syenite.....	153	2.88	3.5	11.5	18.3	11	43
3174	Clarksville.....	do.....	do.....	153	2.88	3.5	11.5	18.3	11	43

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, and Cuba, complete to January 1, 1916—Contd.*

VIRGINIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
7625	Dublin (near).	Pulaski.	Argillaceous limestone.	Pounds. 175	Pounds. 20	3.1	12.7	18.0	22	11
8341	Pulaski.	do.	do.	165	1.86	5.7	7.1	18.3	9	37
(¹).	do.	do.	Carbonaceous dolomite.	175	.54	5.2	7.6	17.0	11	32
8340	Pulaski.	do.	Dolomite.	175	.58	5.2	7.7	17.0	6	46
8342	do.	do.	do.	175	.88	4.4	9.1	17.0	8	49
8343	do.	do.	Siliceous dolomite.	168	1.18	13.3	3.0	17.0	5	47
9405	do.	do.	Dolomite.	178	.46	4.0	10.0	17.0	10	23
7452	Fint Hill.	Rappahannock.	Romblende epidote schist.	187	.96	4.5	8.8	15.8	9	99
1623	Roanoke.	do.	Dolomite.	172	.54	3.4	11.7	16.6	13	87
1624	do.	do.	do.	172	.54	3.4	11.7	16.6	13	22
1624	do.	do.	do.	181	.47	6.1	6.6	17.6	7	44
3357	Lithia.	do.	Limestone.	168	.85	8.2	12.5	16.8	5	33
5461	Roanoke.	do.	Dolomitic limestone.	178	.14	3.9	10.3	18.3	5	33
3450	do.	do.	Quartzite.	162	.58	4.8	10.3	19.4	11	34
4848	Lexington.	Rockbridge.	Limestone.	162	.16	6.5	8.2	15.0	(²)	15
4849	do.	do.	do.	168	.21	4.7	8.4	14.5	7	12
4850	do.	do.	Argillaceous limestone.	168	.12	4.7	8.4	16.3	5	10
4859	do.	do.	do.	168	.12	4.7	8.4	16.3	9	11
5920	Greenee.	do.	Dolomite marble.	178	.33	4.2	9.6	17.3	13	10
4000	Bluffs.	do.	Limestone.	178	.35	4.1	9.7	16.8	10	22
5382	Bluff Water Station.	Rockingham.	do.	168	.35	4.1	11.2	15.5	7	49
5383	do.	do.	do.	172	.79	3.8	10.5	16.4	13	24
6380	do.	do.	do.	168	.24	3.8	11.3	16.3	12	62
5700	Harrisonburg.	do.	Cherty limestone.	156	2.07	8.1	11.6	19.2	7	9
6534	(¹).	do.	Feldspathic sandstone.	165	.54	2.4	13.5	18.7	16	61
6578	(¹).	do.	Calcareous sandstone.	162	.65	2.7	16.5	18.6	11	20
6379	(¹).	do.	Dolomite.	175	.08	5.8	22.2	17.8	9	38
8140	Mount Crawford.	do.	do.	177	.41	2.5	16.0	17.8	23	45
3259	Castlewood.	Russell.	do.	175	.40	2.4	16.9	16.7	13	35
3911	Blackford.	do.	Limestone.	178	.55	5.0	7.9	16.3	4	17
3260	Castlewood.	do.	Argillaceous limestone.	172	.17	5.2	12.7	14.7	8	57
4609	Honaker.	do.	Limestone.	172	.09	4.0	10.1	15.7	10	10
4670	do.	do.	do.	168	.33	4.2	10.9	15.3	21	24
5375	St. Paul.	Shenandoah.	do.	168	.19	5.1	7.8	17.1	(²)	21
3008	Strasburg.	do.	do.	168	.39	5.0	13.2	15.2	4	15
3009	do.	do.	do.	168	.13	5.3	7.1	16.0	5	34
3511	do.	do.	do.	168	.13	5.3	7.3	16.0	5	30
3512	do.	do.	Calcareous sandstone.	175	.22	4.2	9.6	16.0	5	30
5820	(¹).	do.	do.	168	.61	2.7	15.1	15.3	15	84

[illegible]

Exact locality not known.

Test not made.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916*—Contd.

WASHINGTON.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
4539	Lind.....	Adams.....	Basalt.....	Pounds. 184	Pounds. .24	2.2	18.4	18.3	14	25
4540	Asotin.....	Asotin.....	do.....	184	.12	2.3	17.2	18.0	20	34
4562	Zindel.....	do.....	Dolomitic marble.	168	.14	7.5	5.3	(1)	(1)	16
4769	Hoharian.....	Chehalis.....	Basalt.....	178	.37	2.2	18.5	18.2	27	41
4478	Vulcan.....	do.....	do.....	178	.15	2.0	20.0	18.0	17	17
4558	Columbia River Station.	do.....	do.....	178	.18	(1)	(1)	19.0	20	10
4489	Cashmere.....	do.....	Feldspathic sandstone.	162	.73	6.4	6.3	(1)	(1)	67
4524	Wenatchee.....	do.....	Biotite gneiss.	168	.21	5.2	7.8	17.0	28	28
4580	Leavenworth.....	do.....	Granodiorite.	172	.40	7.0	5.7	17.0	(1)	15
2918	Fishers Landing.....	Clarke.....	Olivine basalt.	175	1.33	2.5	16.0	17.8	15	8
2919	do.....	do.....	do.....	168	1.88	2.9	13.2	17.8	13	4
4451	Vancouver.....	do.....	Basalt.....	175	.66	3.0	16.0	17.8	13	4
4454	Yacolt.....	do.....	Altered basalt.	175	.27	2.5	13.8	19.3	19	13
4566	Fisher.....	do.....	Basalt.....	178	.30	2.9	15.8	16.8	15	120
4488	Dayton.....	do.....	do.....	178	.36	2.8	14.3	18.0	25	19
4560	do.....	Columbia.....	do.....	178	.36	2.8	17.4	17.7	16	6
2850	Kelso (3 miles from).....	do.....	do.....	181	.56	3.2	12.6	17.4	21	3
4432	Castle Rock.....	Cowlitz.....	Augite andesite.	181	.17	3.2	7.7	17.4	21	176
4436	Ladu (2 miles northwest of).....	do.....	Basalt.....	187	.29	2.4	16.5	18.8	13	19
4442	Kalama (3 miles north of).....	do.....	do.....	175	.27	3.2	12.5	16.8	11	117
4444	Stella (3 mile east of).....	do.....	do.....	168	.17	2.5	16.1	17.4	15	500+
4468	Carrollton (1½ miles northeast of).....	do.....	do.....	178	1.77	3.3	12.1	17.3	14	7
4496	Stella.....	do.....	do.....	181	.10	(1)	(1)	18.3	22	52
4510	Kalama.....	do.....	do.....	175	.20	3.3	12.2	16.7	10	68
4520	do.....	do.....	do.....	175	.14	3.3	12.0	15.4	10	62
4549	Stella.....	do.....	do.....	181	.23	2.8	14.1	17.2	16	17
4559	Ladu.....	do.....	do.....	184	.11	1.9	20.6	18.0	22	68
4564	do.....	do.....	do.....	181	.12	3.8	10.4	18.0	10	148
4564	Kelso (1 mile south of).....	do.....	Altered basalt.	175	.83	3.9	10.1	14.3	7	500+
4553	Kahloitus.....	Franklin.....	Basalt.....	178	.16	2.9	14.0	17.6	16	9
4452	Danville (½ mile southwest of).....	Terry.....	Altered andesite.	165	1.66	2.9	13.8	18.5	17	39
4429	do.....	do.....	Altered hornblende andesite.	168	.14	3.0	13.3	18.3	13	500+
4459	Keller.....	do.....	Altered andesite.	165	.64	3.1	12.9	17.9	18	140
4481	Cerule.....	do.....	do.....	165	.27	6.5	6.2	(1)	(1)	79
4548	Republic.....	do.....	Limestone.	172	.30	6.6	6.1	17.0	5	40
4433	Cerule.....	do.....	Crystalline limestone.	168	.14	8.9	4.5	14.3	4	13
4509	Republic.....	do.....	do.....	178	.34	6.3	6.4	(1)	(1)	13
4518	Cerule.....	do.....	Biotite granite.	168	.23	4.4	9.0	18.1	8	11
4506	do.....	do.....	Granite.	162	.29	5.3	7.5	18.5	4	6
4542	Laurier.....	do.....	Serpentine.	168	.32	6.7	6.0	(1)	(1)	500+

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

WASHINGTON—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
4502	Oroville.....	Okamogan	Altered hornblende andesite.....	Pounds. 165	Pounds. .88	2.5	16.2	19.1	18	23
4527	Ninthawk.....	do.	Diorite.....	184	.24	4.0	10.0	(¹)	(¹)	24
4073	South Bend.....	Pacific	Basaltic andesite.....	162	4.90	5.9	6.7	15.4	11	500+
4417	(¹).....	do.	Altered basalt.....	175	1.29	4.3	9.3	13.2	15	500+
4431	South Bend.....	do.	Basalt.....	181	.57	2.9	13.6	16.6	6	252
4525	do.....	do.	Altered basalt.....	178	.35	4.0	9.9	13.7	8	177
4511	Holcomb.....	do.	Basalt tuff.....	143	4.87	4.1	9.8	5.7	6	500+
4543	South Bend.....	do.	Basalt.....	175	1.68	3.7	10.8	17.5	10	2
4546	do.....	do.	do.....	178	.63	3.9	10.3	13.7	8	145
4784	Ilwaco.....	do.	Altered basalt.....	150	.83	4.8	8.3	12.3	10	72
4793	do.....	do.	Basalt.....	159	2.13	5.1	7.9	11.0	10	141
4497	Raymond.....	do.	Micaceous sandstone.....	159	2.40	4.9	8.2	4.4	6	39
2123	Takoma.....	Pierce	Altered diabase.....	172	1.70	4.0	10.1	17.7	19	96
4439	Elbe.....	do.	Augite andesite.....	165	.36	4.1	9.8	18.4	9	26
4469	La Grande.....	do.	Altered andesite.....	168	.11	2.2	18.2	19.2	35	20
4534	Elbe.....	do.	Basaltic andesite.....	165	.18	6.6	6.0	(¹)	(¹)	27
4575	Chap.....	do.	Altered andesite.....	153	.36	3.7	10.8	17.7	18	33
6619	Electron.....	do.	Diorite.....	168	.76	2.5	17.4	18.5	20	164
4426	Richardson.....	do.	Altered andesite.....	181	.27	2.5	16.0	18.3	24	102
4505	Olga.....	San Juan	do.....	184	.07	4.2	9.5	17.3	19	48
4470	Friday Harbor.....	do.	Limestone.....	172	.17	2.8	14.3	18.0	17	141
4598	Waldron Island.....	do.	Feldspathic sandstone.....	162	.66	3.1	12.9	13.2	8	21
2141	Deception Pass.....	Skagit.	do.....	168	.81	2.5	15.9	18.5	13	73
4433	Clear Lake.....	do.	do.....	184	.15	2.1	18.9	18.0	20	37
4460	Grassmere.....	do.	Altered diabase.....	184	.22	3.4	11.9	19.3	20	27
4471	Rockport.....	do.	Altered andesite.....	184	.11	10.6	3.8	16.5	18	26
4752	Berlington.....	do.	Slate.....	172	.21	(¹)	(¹)	11.3	6	12
4787	do.....	do.	Altered basalt.....	187	.02	2.9	13.9	18.7	30	11
4474	Cooks.....	Skamania	Basalt.....	175	.98	2.3	17.4	18.2	33	176
8332	Willard.....	do.	Olivine basalt.....	168	.91	7.7	5.2	(¹)	(¹)	8
2145	Whidbey Island.....	do.	Sandstone.....	172	2.53	5.3	7.6	13.3	9	500+
3188	Everett.....	do.	Altered peridotite.....	172	1.02	5.2	7.7	16.2	10	61
3189	do.....	do.	Altered gabbro.....	172	.76	5.2	11.0	17.2	13	88
3190	do.....	do.	do.....	178	.89	3.6	14.6	18.7	17	60
4458	Granite Falls.....	do.	Altered diorite.....	168	.42	2.7	17.7	18.3	17	17
4499	do.....	do.	Diorite.....	168	.43	3.2	12.9	17.6	9	13
4778	Index.....	do.	Granodiorite.....	168	.23	3.1	12.9	17.6	23	16
4464	Monte Cristo.....	do.	Altered andesite.....	172	.12	2.3	17.7	18.3	12	22
4794	Monroe.....	do.	do.....	165	.74	4.3	9.3	15.0	8	72
4485	Granite Falls.....	do.	Serpentine.....	165	.39	8.0	5.0	(¹)	(¹)	179

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

WASHINGTON—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
				Pounds.	Pounds.					
4514	Skamokawa.....	Wahkiakum.....	Basalt.....	175	41	2.2	17.9	18.4	23	12
4530	Cathlamet.....	do.....	do.....	181	22	1.9	21.3	17.7	24	13
4532	do.....	do.....	do.....	175	30	3.1	13.0	17.8	11	10
4572	Tonguet.....	Walla Walla.....	do.....	172	42	3.2	12.5	18.0	6	111
4570	Dixie.....	do.....	do.....	181	39	2.7	14.7	17.2	17	208
1023	Soar Creek.....	Whatcom.....	Altered diabase.....	168	53	3.2	12.8	17.6	17	208
1024	do.....	do.....	do.....	190	73	4.9	8.2	12.8	4	75
1028	Bellingham.....	do.....	Feldspathic quartzite.....	175	19	2.5	16.0	18.2	23	200
4770	Deming.....	do.....	Feldspathic sandstone.....	153	21	2.81	4.9	8.3	5	153
4777	Clinkanait.....	do.....	do.....	156	23	8.2	4.8	9.2	(1)	97
4781	Wickersham.....	do.....	do.....	162	33	15.9	2.5	9.2	(1)	7
4774	do.....	do.....	Sericite schist.....	172	47	23.3	1.7	12.3	22	22
4775	Kendall.....	do.....	Marble.....	173	20	4.0	8.2	17.8	9	16
1272	Collax.....	Whitman.....	Basalt.....	181	11	2.0	20.0	17.7	10	31
1735	Pullman.....	do.....	do.....	184	15	2.5	16.3	19.0	25	11
4456	Winona.....	do.....	do.....	181	15	2.7	14.7	17.6	26	13
4491	Rossia.....	do.....	do.....	175	29	2.3	17.2	(1)	(1)	22
4503	Pullman.....	do.....	Altered basalt.....	184	11	2.3	17.7	18.7	9	3
4529	Palouse.....	do.....	Basalt.....	165	40	2.0	16.3	18.0	13	13
4494	Sequoia Butte.....	do.....	Quartzite.....	181	34	2.5	13.2	17.5	(1)	21
4428	North Yakima.....	Yakima.....	Basalt.....	181	54	2.0	13.2	17.5	16	120
4512	do.....	do.....	do.....	178	57	2.0	13.2	17.5	(1)	13
4582	do.....	do.....	Basalt.....	178	57	2.0	13.2	17.5	(1)	21
4583	do.....	do.....	do.....	172	55	2.2	18.2	17.7	24	120
4584	do.....	do.....	do.....	181	26	2.0	18.2	16.8	11	13
4585	do.....	do.....	do.....	181	24	2.0	16.6	17.7	25	3
4788	do.....	do.....	do.....	175	37	2.7	14.6	17.7	11	7
4786	do.....	do.....	Granodiorite.....	175	39	2.5	11.6	17.8	21	9
4791	do.....	do.....	Altered andesite.....	178	20	3.9	10.3	17.2	21	7
4792	do.....	do.....	Augite andesite.....	175	11	2.0	20.2	19.2	38	13

WEST VIRGINIA.

3030	Phillippi.....	Barbour.....	Sandstone.....	156	1.41	6.6	6.0	16.1	8	12
3073	Nicklow.....	do.....	do.....	159	84	4.2	9.4	18.8	9	3
3106	Phillippi.....	do.....	do.....	156	3.38	4.8	8.3	6.4	5	68
3108	do.....	do.....	Limestone.....	172	1.34	3.6	11.0	16.8	17	41
2488	Martinsburg.....	Berkeley.....	do.....	168	26	4.8	8.3	16.7	4	52

2006	do.	do.	168	11	4.1	9.8	15.7	8
2607	do.	do.	168	20	4.2	9.6	16.4	4
3074	do.	do.	172	12	3.5	11.4	16.4	10
5365	Berkeley	Siliceous limestone	168	21	4.6	8.6	16.0	7
5893	Martinsburg	do.	168	33	3.5	11.4	15.8	10
8154	do.	Argillaceous limestone	178	17	2.8	14.3	17.2	3
8153	do.	do.	168	35	4.1	9.8	15.7	8
8504	do.	Limestone	168	70	5.4	7.4	13.7	3
8586	do.	Siliceous dolomite	178	37	3.6	11.2	17.2	17
7969	Martinsburg	Dolomite	178	26	2.5	15.9	17.3	13
3105	Peytona	Sandstone	159	1.99	3.4	11.8	16.8	12
3102	Gassaway	do.	156	4.65	3.5	11.6	12.7	70
4645	Sutton	Feldspathic sandstone	156	3.07	17.9	2.2	17.8	42
3107	Welshburg	Limestone	162	56	3.1	12.7	(1)	1
1777	Huntington	Sandstone	162	2.32	9.5	4.2	0.0	(1)
2417	do.	Feldspathic sandstone	159	3.43	7.4	5.4	14.7	6
2418	do.	Calcareous sandstone	162	1.41	4.9	8.2	15.7	23
2485	do.	Weathered sandstone	162	3.18	28.4	1.4	12.2	65
3021	do.	do.	147	2.60	41.7	1.0	(1)	30
3029	do.	Calcareous sandstone	165	.99	3.3	12.1	14.2	77
1884	do.	Dolomitic limestone	165	1.40	4.4	9.2	15.2	62
1885	do.	Limestone	165	1.14	4.4	7.4	11.0	8
3034	Big Bend	Calcareous sandstone	165	1.48	5.4	(1)	16.7	9
3093	Doddridge	Sandstone	156	3.25	13.5	3.0	11.3	5
3022	Greenbrier	Cherty limestone	168	7.1	7.1	5.6	(1)	22
3069	Organ Cave	Limestone	168	26	4.1	9.8	15.8	31
5917	Penick	Crystalline limestone	168	16	3.7	10.7	16.8	45
5918	Frazier	Limestone	172	26	3.7	10.8	(1)	38
5919	Snowflake	do.	163	1.63	5.5	7.3	(1)	14
3026	Avon	Sandstone	159	1.09	2.2	13.7	18.0	14
3427	Ridgely	Limestone	168	.82	3.2	11.4	16.8	9
3428	Hampshire	do.	168	.89	3.3	11.4	16.8	54
7417	Green Spring	Siliceous limestone	165	.29	9.1	11.0	17.9	63
7418	Green Spring (1 1/2 miles west of)	Quartzite	159	.75	3.5	11.5	13.5	68
3027	Lost Creek	Sandstone	153	5.22	6.8	5.8	9.5	13
5948	Clarkburg	Argillaceous limestone	172	.87	3.5	11.4	16.5	69
3000	Union District	Sandstone	156	3.54	9.6	4.2	4.5	49
3031	Ripley (near)	do.	156	3.60	5.0	8.0	6.4	29
31303	Silverton	do.	156	4.02	6.3	6.4	8.0	36
22489	Engles	Limestone	168	.30	4.5	9.0	11.8	4
22490	Kearneysville	do.	172	.63	4.4	9.6	14.7	68
2579	Millville	Dolomitic limestone	175	.74	4.4	9.1	14.3	5
2589	Kearneysville	Limestone	168	.22	3.9	10.2	14.3	29
3025	Middleway	do.	172	.72	4.0	10.1	15.8	10
3032	Summit	Dolomitic limestone	175	.82	2.9	13.8	17.5	22
5741	Charlestown	Limestone	168	.19	4.1	9.7	16.8	7
2634	Millville	Dolomite	178	.29	3.7	10.9	16.6	6
2965	St. Albans	Limestone	168	.54	4.9	8.2	16.4	4
2969	Kendalia	Feldspathic sandstone	159	3.37	6.6	6.1	15.8	31
2970	Tornado	Sandstone	156	3.94	8.8	4.6	0.0	50
								6

¹ Test not made.

Exact locality not known.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

WEST VIRGINIA—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent. of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
3072	(1) Spring Hill.	Kanawha.	Sandstone	Pounds. 139	Pounds. 2.32	11.0	3.6	14.6	4	34
6109	Blakeley	do.	do.	139	1.96	14.6	2.7	12.1	4	25
3023	Weston.	do.	Siliceous slate	162	1.88	4.8	8.3	19.7	30	19
3104	Camden.	Lewis.	Sandstone	165	2.30	4.1	9.8	9.9	17	51
3238	Logan.	do.	Limestone	168	1.40	(2)	(3)	16.7	15	32
2972	Chapmanville.	do.	Feldspathic sandstone	139	2.56	6.4	6.3	13.2	5	40
3237	Kitchen.	do.	Sandstone	139	2.83	2.6	13.2	8.3	8	52
4760	Fairmont.	Marion.	Argillaceous sandstone	165	2.44	4.5	8.9	12.0	14	39
7833	do.	do.	Ferruginous sandstone	156	2.39	4.8	8.3	12.0	8	44
7493	do.	do.	Argillaceous limestone	(3)	(2)	3.4	11.8	17.5	10	49
7494	do.	do.	Feldspathic limestone	(4)	.47	7.8	5.1	11.8	5	59
7785	do.	do.	Argillaceous limestone	168	.50	4.3	9.3	16.8	7	26
7834	do.	do.	do.	171	.29	3.4	11.8	17.2	11	24
8854	do.	do.	do.	153	4.52	8.3	4.8	16.2	9	22
2967	Union District.	Mason.	Feldspathic sandstone	150	5.30	(2)	(2)	0.0	6	70
2976	Point Pleasant.	do.	do.	165	.82	3.0	13.5	13.5	8	77
2088	North Fork	McDowell.	do.	156	2.37	4.3	9.4	14.9	10	149
2974	Elkhorn.	do.	Ferruginous sandstone	162	2.16	4.2	9.4	16.8	9	98
2997	Berwind.	do.	Sandstone	162	1.61	3.3	12.2	16.0	8	208
3036	Gary.	do.	Feldspathic sandstone	165	3.53	4.2	9.6	15.0	8	61
4622	Welch.	do.	do.	165	1.60	4.3	9.2	(2)	(2)	108
2995	Bluefield.	Mercer.	Limestone	168	.51	3.3	12.0	16.8	11	58
2970	do.	do.	do.	188	.19	7.3	5.5	(2)	(2)	75
7740	Princeton (near)	do.	Argillaceous limestone	162	1.35	(2)	(2)	13.2	7	45
7735	do.	do.	Feldspathic sandstone	188	.38	5.8	6.9	13.4	15	76
7764	do.	do.	Calcareous sandstone	165	1.21	3.7	11.1	17.0	11	22
8746	do.	do.	do.	165	.35	4.0	10.0	16.2	7	43
2472	Keyser.	Mineral.	Limestone	168	.22	4.1	9.8	18.8	13	40
3350	Paterson Creek Station.	do.	do.	165	.19	5.0	17.1	18.8	23	81
3351	do.	do.	do.	168	.50	5.6	7.1	(2)	(2)	37
767	Morgantown.	Monongalia.	do.	168	1.33	3.6	11.2	17.2	12	21
3065	Randall.	do.	do.	168	.46	4.7	8.6	17.1	11	29
3071	Morgantown.	do.	Siliceous limestone	168	.23	4.9	8.2	16.1	10	76
5610	Sturgasson.	do.	Limestone	168	.55	4.4	9.1	16.0	6	32
5612	do.	do.	Argillaceous limestone	168	.74	4.3	9.3	14.2	4	16
5613	do.	do.	Impure limestone	168	.48	4.3	9.4	16.0	10	32
5615	do.	do.	Argillaceous limestone	168	.37	3.8	10.	15.9	10	30
5616	do.	do.	Feldspathic limestone	168	.37	3.8	10.	15.9	10	30
2513	Opekiska.	do.	Argillaceous limestone	156	3.74	6.9	5.8	14.7	5	36
2514	Morgantown.	do.	Feldspathic sandstone	150	2.51	11.2	3.6	15.2	5	11
3024	Smithtown.	do.	Ferruginous sandstone	134	4.04	6.1	6.6	(2)	(2)	46
3033	Daybrooke.	do.	do.	153	3.61	(2)	(2)	14.0	9	24

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WISCONSIN.

6452	Greenleaf.....					
6304	Brillon.....	Brown.....	172	2.30	3.0	13.3
6161	Columb.....	Calumet.....	165	1.35	7.5	5.3
5788	Columb.....	Columb.....	165	2.75	7.0	12.2
	Bridgeport.....	Argillaceous dolomite.....	165	5.7	12.7	29
	Crawford.....	Siliceous dolomite.....	102	3.10	8.9	9.8
		Dolomite.....	172	2.30	3.0	13.3
		do.....	165	1.35	7.5	5.3
		Argillaceous dolomite.....	165	2.75	7.0	12.2
		Siliceous dolomite.....	102	3.10	8.9	9.8
						5
						42
						5
						8
						58

¹ Exact locality not known.

² Test not made.

TABLE V.—Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—Contd.

WISCONSIN—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Commenting value.
6209	Soldiers Grove.	Crawford.	Dolomite.	Pounds. 162	Pounds. 2.96	8.4	4.8	11.3	4	24
6216	Prairie du Chien.	do.	do.	165	2.65	7.0	5.7	5.8	4	4
6223	Bridgeport.	do.	do.	175	.65	(1)	(1)	12.7	8	20
746	Madison.	Paine.	Rhyolite.	165	.09	2.4	17.0	(1)	(1)	(1)
1009	do.	do.	Dolomite.	165	2.70	9.0	4.4	14.0	7	174
5362	(2)	do.	Argillaceous limestone.	168	2.30	4.3	9.4	14.7	8	30
6062	(2)	do.	Dolomite.	175	1.21	8.9	4.5	14.0	10	34
6202	(2)	do.	do.	162	1.67	3.6	11.1	(1)	(1)	19
6063	(2)	do.	Siliceous dolomite.	172	1.57	6.1	6.6	11.3	6	19
6228	Middletown.	do.	Oolitic dolomite.	172	1.90	5.1	7.9	15.7	10	14
6438	Madison.	do.	Argillaceous dolomite.	162	2.09	10.8	3.7	12.5	10	14
1397	Portland.	Dodge.	Quartzite.	168	1.53	2.8	14.2	19.0	19	94
5790	Richwood.	do.	Dolomite.	172	1.53	4.4	9.1	16.1	11	34
6300	Hubard.	do.	Argillaceous dolomite.	172	1.10	4.5	9.0	14.2	12	53
5946	Sturgeon.	Door.	do.	178	.26	3.8	10.6	12.8	(1)	6
6244	Kewaunee.	do.	Dolomite marlite.	178	.22	17.1	2.3	(1)	(1)	53
5795	Commonwealth.	Florence.	Ferruginous slate.	168	.51	5.4	7.5	13.7	8	86
5223	Pecks.	Fon du Lac.	Dolomite.	178	.51	3.4	11.9	14.3	7	35
6203	Marblehead.	do.	do.	175	.30	4.6	8.7	13.2	17	18
6479	do.	do.	do.	178	.30	3.7	10.8	13.8	7	52
6752	do.	do.	do.	175	.30	3.2	5.1	13.4	6	27
6807	Hemilton.	do.	do.	175	1.01	5.2	6.1	13.4	6	49
6210	Benton.	Grant.	do.	168	2.16	12.9	3.1	12.8	4	16
6230	Cassville.	do.	do.	168	1.43	9.6	4.2	12.3	4	39
6222	Hazel Green.	do.	Siliceous dolomite.	165	1.88	7.1	5.0	15.2	5	18
6212	Lanesburg.	do.	Dolomite.	162	1.67	4.1	9.7	14.8	8	21
6208	Platteville.	Greene.	Argillaceous dolomite.	172	1.37	7.4	5.4	15.0	5	15
6215	Monroe.	do.	do.	172	1.68	22.5	1.8	(1)	(1)	18
6221	Brinthead.	do.	Siliceous dolomite.	162	4.97	8.8	4.5	9.3	3	41
6225	Marathon.	do.	do.	162	3.33	11.4	3.5	16.2	5	33
6227	Broadhead.	do.	Dolomite.	162	4.72	11.1	3.6	14.1	4	27
717	Utley.	Greene Lake.	do.	172	.87	4.1	9.8	(1)	(1)	8
667	Berlin.	do.	Rhyolite.	165	.05	1.8	22.5	(1)	(1)	15
668	do.	do.	do.	165	.03	4.0	10.0	(1)	(1)	10
695	do.	do.	do.	165	.04	5.0	8.0	(1)	(1)	8
1026	Utley.	do.	do.	165	.06	5.6	7.2	(1)	(1)	(1)
1427	do.	do.	do.	165	.10	1.9	20.6	19.0	23	35
1434	Berlin.	do.	do.	162	.05	2.5	16.2	18.9	19	5
6207	Blue Mound.	Iowa.	Argillaceous dolomite.	162	4.75	11.3	3.6	10.7	4	17
6213	Mineral Point.	do.	Limestone.	168	.59	6.2	7.7	15.7	6	9
6211	do.	do.	do.	165	2.96	3.9	10.3	14.5	11	21

TABLE V. — *Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916*—Contd.

WISCONSIN—Continued.

Serial No.	Town or city.	County.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Commenting value.
6159	Whitewater	Walworth	Dolomite	168	2.27	6.4	6.3	13.3	7	27
3509	Lannon	Waukesha	do	175	.91	3.4	11.7	15.9	13	24
3800	do	do	do	172	1.12	3.2	12.7	16.1	13	26
6170	Pewaukee	do	do	172	1.84	4.1	9.9	15.3	13	14
6171	Lannon	do	do	168	2.03	6.7	6.0	13.3	9	36
6172	Waukesha	do	do	172	1.56	3.6	11.0	15.0	7	20
6173	Lannon	do	do	175	1.88	3.5	11.6	15.6	10	22
8656	do	do	do	175	.85	3.6	11.1	15.4	10	25
1408	Waukegan	Winnebago	Granite	162	1.96	1.4	27.8	18.9	20	6
8011	Waukegan (2 miles north of)	do	Bioline granite	168	1.15	5.3	7.5	19.0	9	26
8018	Waukegan	do	do	168	.25	4.1	9.7	18.7	5	20
1574	Lohrville	Waukegan	Granite	168	.26	2.0	20.0	19.0	(1)	6
1540	do	do	do	(1)	(1)	2.4	16.4	(1)	(1)	(1)
1435	Marion	do	do	165	.30	1.5	26.3	18.9	23	7
1432	Lohrville	do	do	165	.19	2.7	14.6	18.4	21	9
1431	Red Granite	do	do	165	.14	2.7	37.0	18.8	25	3
1398	Clan Rock	do	do	165	.42	1.5	27.4	19.2	21	6
5586	Red granite	do	do	(1)	(1)	(1)	(1)	19.0	14	(1)
6227	Oshkosh	Winnebago	Sandstone	175	.65	3.8	10.6	15.5	8	37
6226	Appleton	do	Dolomite	175	.53	3.4	11.8	16.5	10	45
6246	Ouro	do	do	172	1.65	5.6	7.1	16.3	7	32
6847	Neenah	do	do	175	.62	3.4	11.9	14.7	11	33
6873	Neenah	do	do	168	2.68	4.1	9.8	14.2	9	31
5920	Rudolph	W. do.	Sandstone	158	1.10	3.4	11.8	18.7	5	32
5796	(2)	(2)	Ferruginous sandstone	140	4.51	25.2	1.6	0.0	3	20
6181	(2)	(2)	Argillaceous dolomite	168	1.86	10.7	3.7	11.7	7	9
6180	(2)	(2)	do	168	2.96	10.7	5.5	15.0	7	18
6179	(2)	(2)	do	153	6.90	7.3	5.5	12.7	5	19
6177	(2)	(2)	do	165	2.82	6.1	6.6	12.7	5	26
6176	(2)	(2)	do	165	3.56	7.6	5.2	4.0	3	13
6175	(2)	(2)	do	168	2.67	7.4	5.2	13.3	12	32
6175	(2)	(2)	do	168	2.91	5.4	7.4	13.2	16	13
6185	(2)	(2)	do	168	2.04	8.1	4.9	15.0	7	23
6186	(2)	(2)	Siliceous dolomite	162	3.68	9.0	4.1	4.5	2	22
6183	(2)	(2)	do	162	2.51	8.0	5.0	12.0	9	27
6178	(2)	(2)	Dolomite	172	1.32	5.6	7.1	15.5	11	25
6174	(2)	(2)	do	150	3.13	11.3	3.5	11.7	4	32
6182	(2)	(2)	do	175	3.86	9.2	4.3	13.7	4	33
6184	(2)	(2)	do	162	3.44	8.6	6.5	14.5	4	20
6231	(2)	(2)	do	162	3.83	8.6	11.0	14.0	10	24
5791	(2)	(2)	do	168	3.41	6.5	6.2	16.0	9	38
6232	(2)	(2)	do	165	3.41	6.5	6.2	16.0	9	38

6233 7624	(²) (²)	Argillaceous limestone. Dolomite.	165 168	.78 .79	6.2 7.3	(¹) 14.0	(¹) 6	28 36
WYOMING.								
6452 2209 2380	Sheridan. do. do.	Ferruginous sandstone. Calcareous sandstone. do.	150 168 165	7.55 1.49 1.86	14.4 2.7 4.2	2.8 15.0 9.6	5.0 15.3 15.3	3 97 251
CUBA.								
471 472 575 473	Cienfuegos. Campo Florida. Habano. do.	Andesite. Diorite. do. Marble.	159 172 168 168	2.04 .66 .81 1.04	2.6 3.4 2.2 4.0	15.3 11.7 18.3 10.1	(¹) (¹) (¹) (¹)	337 137 148 90
PORTO RICO.								
795 798 799 803 797 801 802 793 794 796 800 804	Bayamon. Carolina. Rio Piedras. do. do. Arecibo Utrado Manati do. Rio Piedras Cayey Juncos Comerio. Gurabo	Limestone. do. Basalt tuff. do. Diorite. Limestone. do. do. Diorite. Limestone. Basalt breccia.	165 168 162 168 156 168 165 168 168 175 168 187	0.60 .49 .83 1.10 .87 .39 .96 .20 .08 .09 .11 .25	5.3 5.2 6.3 3.5 7.4 4.0 5.2 5.8 5.1 2.8 6.0 3.5	7.5 7.7 6.3 11.3 5.4 10.0 7.7 6.9 7.9 14.5 6.7 11.5	(¹) (¹) (¹) (¹) (¹) (¹) (¹) (¹) (¹) (¹) (¹) (¹) (¹)	49 27 91 108 48 59 64 30 61 1 135 73
CANADA.								
6660 6728 6729 7661 2213 7079 2510 3819 6136 6300 6518 7009	Vernon. do. do. Endrick Fortlock Harbor do. Thessalon. Desbarats. Humbug Point. Bruce Mines. do. do.	British Columbia. ³ do. do. do. Ontario. ³ do. do. do. do. do. do. do.	168 165 162 153 172 172 163 178 181 187 184 187	0.36 .55 1.45 4.87 .57 .07 .22 .86 .18 .17 .72 .09	(¹) 4.4 3.5 5.9 3.0 2.8 1.9 2.5 2.2 2.1 2.3	(¹) 9.1 6.8 13.2 14.3 20.6 (¹) 15.8 18.2 19.4 17.4	12.4 18.4 18.3 18.3 16.9 16.9 17.3 18.0 18.5 18.0 18.6	5 8 41 8 19 10 12 10 9 26 31 17

³ Province.² Exact locality not known.¹ Test not made.

TABLE V.—*Results of physical tests of road-building rock from the United States, Canada, Porto Rico, and Cuba, complete to January 1, 1916—(Contd.)*

CANADA—Continued.

Serial No.	Town or city.	Province.	Name of material.	Weight per cubic foot.	Absorption per cubic foot.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing value.
7387	Bruce Mines.	Ontario	Altered diabase.	Pounds, 178	0.70	2.6	15.4	17.3	15	109
7388	do.	do.	do.	184	.25	2.5	16.3	18.7	20	155
7389	Halelock.	do.	do.	190	.08	2.2	18.2	18.7	16	22
7390	Cape Breton.	do.	Open hearth slag.	196	1.68	3.1	12.9	(1)	(1)	500+
5367	Pole Island.	do.	Altered gabbro.	175	.10	2.3	17.6	17.2	9	47
6889	Desbarats.	do.	do.	175	.10	5.1	7.8	16.1	6	35
7188	do.	do.	do.	184	.44	3.7	10.7	17.8	16	104
5831	Bruce Mines.	do.	Altered augite andesite.	181	.34	2.1	18.7	17.9	22	39
7256	Belmont Township.	do.	Altered Andesite.	187	.28	(1)	(1)	18.5	9	39
5933	Dundas.	do.	Dolomite.	175	1.17	2.9	13.7	15.8	14	27
7269	Fergus.	do.	do.	165	.40	(1)	(1)	15.8	5	48
7270	Owen Island.	do.	Argillaceous dolomite.	165	2.25	(1)	(1)	14.8	3	39
7671	do.	do.	Siliceous dolomite.	165	1.25	(1)	(1)	18.3	3	62
7672	Dundas.	do.	Dolomite.	175	.57	5.3	7.5	16.6	14	41
8163	do.	do.	do.	172	.83	5.5	7.3	14.1	6	17
8164	do.	do.	do.	175	.35	3.9	10.0	15.8	13	36
8165	do.	do.	do.	175	.57	3.7	10.9	16.2	9	46
8166	do.	do.	do.	175	.24	3.6	11.1	16.0	11	61
8167	do.	do.	do.	168	.66	3.8	10.5	13.5	10	19
8168	do.	do.	do.	172	.52	3.8	10.5	15.8	6	26
7372	do.	do.	do.	168	.95	3.0	13.4	12.8	8	50
6168	Copley Island.	do.	Feldspathic sandstone.	190	1.30	2.5	16.3	18.2	34	33
7251	Modoc Township.	do.	Altered diorite porphyry.	190	.17	3.0	13.2	17.8	13	79
7252	Elzvir Township.	do.	Quartz diorite.	190	.10	(1)	(1)	18.3	16	34
7253	Belmont Township.	do.	Hornblende epidote schist.	187	.19	2.9	13.6	17.9	13	47
7254	do.	do.	Amphibolite.	187	.31	(1)	(1)	18.3	24	87
7257	do.	do.	do.	193	.11	(1)	(1)	18.6	17	57
7255	Elzvir Township.	do.	Hornblende gneiss.	199	.19	(1)	(1)	17.6	9	48
7266	Collingwood.	do.	Argillaceous limestone.	165	1.39	(1)	(1)	10.3	4	40
7283	do.	do.	Limestone.	165	.93	(1)	(1)	18.8	12	119
8873	Hagersville.	do.	Siliceous limestone.	175	.93	3.5	11.3	19.0	11	23
5725	Sherbrooke.	Quebec	Siliceous limestone.	175	.31	3.6	11.2	17.7	14	22
7303	Dundas.	Ontario	Dolomite.	172	.91	(1)	(1)	15.8	10	19
7305	do.	do.	do.	173	.91	(1)	(1)	15.3	10	36
7333	Galt.	do.	do.	168	1.72	4.2	9.6	15.3	7	35
7367	Dundas.	do.	do.	173	.93	3.6	11.2	15.4	11	33
7368	do.	do.	do.	172	.65	3.8	10.4	13.9	13	68

² Exact locality not known.¹ Test not made.

UNITED STATES DEPARTMENT OF AGRICULTURE



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PATRONAGE DIVIDENDS IN COOPERATIVE GRAIN COMPANIES.

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INTRODUCTION.

The by-laws of a great many cooperative associations provide for the payment of dividends to their patrons prorated in direct ratio to the amount of business carried on between the organization and the individual members. In a great majority of those organizations these provisions have not yet been put into effect.

The principle of patronage dividends has been understood by students of cooperation from the beginning, but has only lately been making itself felt among the rank and file of the great body of intending cooperators of America. The organization of farmers' elevators, having had its origin at a time when cooperation on the North American continent had not been the subject of much study, quite naturally sought the lines of least resistance. It is natural, then, since the corporation law was well founded and in successful

NOTE.—This bulletin should be of interest to farmers' cooperative grain elevators and warehouses, and to members of these companies. It should be of interest to farmers and others who are forming new cooperative grain elevators and warehouses.

33235°—Bull. 371—16

operation, that the vast majority of these organizations were chartered under this law.

The central idea of these farmers was that of pure cooperation, as evidenced by the insertion of cooperative clauses in the by-laws of many of these companies, but the vehicle through which cooperation was to be carried out was not provided for by law, except in a few instances, and fundamentally was not intended to carry out the purposes for which the farmers then sought to use it. Later, when laws were passed providing for the distribution of dividends upon a cooperative basis, apathy on the part of the management of the elevators and obstacles contingent upon their organization as corporations delayed the readjustment of these companies to the new conditions. The organization of a new cooperative company where cooperative laws are in effect is a simple matter in comparison with the readjustment of a company which has been in business for several years, has accumulated a surplus, and taken on business relations of a complex nature.

It is not difficult in itself to provide a means of paying patronage dividends when conditions regarding the organization of an association have been prearranged for that purpose. The difficulties which confront the majority of cooperative elevators at the present moment are matters of organization or reorganization rather than of method. Where the organization has been perfected under some modern cooperative law, the adjustment to a patronage dividend basis is practically automatic. If there are difficulties, they are encountered in providing a method of distribution which shall be at the same time economical and efficient.

It is in the older organizations, founded under the corporation law, that the greater difficulties arise. The cooperative laws of the State under whose jurisdiction the elevator is operated, usually provide the conditions under which new organizations may be formed and old ones converted to the provisions of the cooperation statute.

COOPERATIVE ORGANIZATION IN RELATION TO PATRONAGE DIVIDEND PAYMENTS.

In discussing the relation of cooperative elevator organization to patronage dividend payments, elevator companies may be grouped under several heads or classes. Treating these progressively from the earlier types to the more complex later organizations, we should first consider the single community elevator company organized as a corporation. It should be understood that the method of adaptation to the patronage dividend basis applies only to such elevators as are properly under the jurisdiction of a cooperative law.

In the case of old organizations, it may be stated generally that it is safe to reorganize a corporate company under conditions which will

satisfy its debts and distribute its surplus to the stockholders, thus reducing the organization to the relative basis upon which it began business. The distribution of the surplus to the corporation stockholders before reorganizing is important, since it is held under the corporation law that the earned surplus is held for the benefit of the stockholders. Aside from this procedure, the company should comply with the provisions of law peculiar to the State in which it is located, so that it may transact its business legally as a cooperative concern.

The single elevators organized from the beginning under the cooperative law constitute the second class. This class also will include the elevators just described after their reorganization.

A third class may be designated as the county unit plan, such as is found operating in Kansas under the control of the Farmers' Union. Under this arrangement, all the elevators belonging to a county union are banded together as one cooperative association and transact business as a unit. In order to keep a close check upon the business under the varying conditions of management in the several elevators represented, it has been found advisable to keep the records of the company in such a manner as to show the individual earning percentage of each elevator.

As these records are kept in a general office, the distribution of the patronage dividend payments from the controlling office is possible and may be provided for either by paying a uniform rate to all the patrons or by varying the rate according to the percentage of profit in each of the elevators.

The companies of the fourth class are in many particulars similar to those of the third class or county unit plan, but are organized on a greatly extended scale.¹ In addition to the activities usual to primary elevators these companies have entered the terminal market upon the same basis as a commission company, holding memberships on boards of trade and doing an extensive commission business. Such companies have not been able to pay a patronage dividend, although specifically organized with the privilege of doing so.

The inability to pay patronage dividends when operating as a commission company has been due to the existence of the commission rule commonly applied between members in the various boards of trade and chambers of commerce. This rule, prohibiting as it does the returning of any part of a trader's profits to the shippers upon the ground that such would constitute a rebate, practically precludes the possibility of paying patronage dividends. Where all earnings and net profits are figured upon the whole business transacted by the company as a unit it is impracticable, under this rule, to divide the profits upon any but a stock dividend basis.

¹ Companies operating under the fourth class are at present confined to the Canadian Northwest.

Under the fifth division may be considered the companies which are similar to those operating under division four where all the profits are retained in the locals, or pooled in the general treasury to be prorated according to the business of the patrons, but with this difference—that the companies themselves do not enter upon any business except that properly belonging to primary elevators. In order to secure the benefits of trading on the board of trade a company organized explicitly for that purpose might be employed. All the stock in such a corporation could then be owned either by the several stockholders of the primary elevator company or by the elevator company itself if so authorized under the law.

The profits accruing to such a company in the first place could be distributed to the individual stockholders, or in the second case could be paid into the general treasury of the primary elevator company and there prorated to the several locals according to the amount of business each had transacted. Under present conditions of the market any plan of organization which attempts the distribution of patronage dividends which in any way embrace profits accruing to the organization on the boards of trade doubtless would meet with opposition.

ACCOUNTING AND BUSINESS PRACTICE IN RELATION TO PATRONAGE DIVIDEND PAYMENTS.

Business methods employed to effect the complete distribution of profits derived from the transaction of business in cooperative companies and societies are at present in the experimental state. The newness of the application of thoroughgoing cooperative methods has not given time for an extended study of those business and accounting requisites necessary for the scientific operation of the business. In privately operated elevators the same need has not been felt for accurate records and improved business methods as has arisen since cooperative methods of transacting the business of agricultural marketing organizations became general. Because each member of a cooperative organization is in fact an interested partner, and to some extent feels a personal responsibility for the success of the association, it has become imperative in such societies or companies that their methods of operation and systems of accounts be clear, comprehensive, and at the same time easily understood.

DESIRABILITY OF STANDARDIZATION OF ACCOUNTING RECORDS.

Progress in cooperative methods of handling grain has been so rapid that in many cases the business has outgrown the methods which were borrowed from other lines of operation. Systems of accounts and plans of operation have been tried which often were not suited to the needs of the business. For every reason it would seem the part of wisdom for leaders in the movement to work to-

ward the standardization of the operation of cooperative marketing organizations,¹ and especially should they unite on a uniform system of accounting records.

DIVERSITY OF CONDITIONS AND METHODS OF DISTRIBUTION.

The methods of distribution of dividends, however, must be modified to fit the varying conditions under which elevators operate. The cooperative principle of marketing is applied to the single community and to areas embracing counties and even districts of several counties each. Any method of doing business which contemplates the management of these organizations must be as varied as the business with which it is used. In dealing with such methods or systems the general classes of enterprises previously outlined will be considered, but since few elevator organizations are able to conduct their business under exactly the conditions of any of the groups cited, it is probable that a determination of profits on a pro rata basis necessarily will be a combination of some of the plans described.

PATRONAGE DIVIDEND RECORDS.

The method of accounting in a single cooperative elevator is not unlike that which would be employed in any other single elevator, except that certain records must be kept which will show the total business transacted between the elevator and each of its patrons. This total includes the business conducted by the elevator of both purchasing and selling. For the single elevator the simplest method of accounting for the business transactions can be obtained through the use of what may be called the patronage ledger. This ledger is so arranged as to receive the tabulation of bushels and pounds of each kind of grain purchased and of the selling value of all commodities of merchandise sold. The record of grain purchased may be obtained from the stubs of the checks given in payment for grain, and the amount of sale of each kind of merchandise may be similarly obtained from the duplicates of the sales tickets. In this ledger the requisite number of sheets is assigned to each customer, so that at the end of the year the total business transacted with each patron is recorded under his name.

BASIS OF DISTRIBUTION.

When the books of record of the company have been closed for the year and the profit determined a certain percentage on the capital stock outstanding can be paid as a dividend. After deducting this percentage from the total amount of profit a determination can be made of the amount of money still on hand available for distri-

¹ Kerr, W. H., and Nahstoll, G. A.: Cooperative organization business methods, U. S. Department of Agriculture, Bulletin 178. 1915.

bution as a patronage dividend, and this may be distributed accordingly, allotting a certain amount per bushel to the transaction in grain and a certain percentage of the value of the goods sold to the merchandise transaction. It should be the practice of cooperative organizations to set aside all reserves and additions to surplus before paying either the stock or patronage dividends.¹

Considerable difference of opinion has arisen regarding the proper basis for distribution of patronage dividends on transactions in grain. It has been held by certain managers and boards of directors that the value of grain purchased should be the basis for distribution, but investigations by the Office of Markets and Rural Organization show that distribution should be made on the basis of quantity handled.

In handling grain the management of an elevator usually determines upon a certain net margin between the purchasing and selling value which it assumes will yield sufficient revenue to carry on the business. Almost without exception this margin is the same on all varieties of grain. It must be apparent, therefore, that, since this margin yields whatever profit accrues to the elevator, it would not be equitable to pay a patron hauling oats at 38 cents a bushel a smaller patronage dividend on the same number of bushels than might accrue to a patron hauling wheat at \$1.10. If the value of the grain determined the profit, a value basis could be established for determining patronage dividends; but the fact that two patrons hauling the same kind of grain at different times of the year under conditions of price fluctuation would receive varying amounts of money for the same number of bushels of the same commodity shows that this is not the proper basis for patronage dividend distribution.

THE PATRONAGE LEDGER.²

In attempting to consider the application of cooperative accounting methods to the county unit or district plan, a transition is made from a very simple plan of organization to one of greater complexity and to a plan which in its accounting requirements makes demands for an extension of the idea contained in the patronage ledger. Throughout the consideration of accounting requisites for cooperative elevators, the patronage ledger will always remain the basis to be relied on for data. As the complexity of organization increases, however, the patronage ledger takes on a new form and develops into a comprehensive filing system. The patronage ledger

¹ Bassett, C. E., Moomaw, Clarence W., and Kerr, W. H.: *Cooperative Marketing and Financing of Marketing Associations*, U. S. Department of Agriculture, Yearbook, 1914. See p. 196.

² Humphrey, John R., and Kerr, W. H.: *A System of Accounts for Farmers' Cooperative Elevators*, U. S. Department of Agriculture, Bulletin No. 236. 1915. See p. 10.

in book form becomes too cumbersome to be economically feasible for daily use under these more complex conditions.

In the county plan several elevators are grouped together into a single unit, with the control centering in a general office supervised by a general manager. As any system of accounts devised for this type of organization should aim to minimize the work of each local manager, all accounting, except such as is required for the recording of sales of merchandise to local patrons, is recorded in the central office. In this case a system of grain-purchase tickets will take the place of the patronage ledger. Each station manager will record upon a suitable ticket all the grain received from a certain patron during a business day. At the end of the day these tickets will be forwarded to the central office, together with the report of all the business transactions of the day. At the central office these grain-purchase tickets should be alphabetized by the names of the patrons. If the grain has been received and not paid for, such tickets are filed according to number in another compartment of the filing drawer, to be removed to the alphabetical file upon notice that the grain has been purchased. By this method of filing it becomes possible, through the use of an adding machine, to arrive at the business transacted with each of the patrons during any period by simply adding together the totals of the tickets registered under each name. In the case of sales of merchandise, a similar filing system should be used, each of the patron's purchases being filed under his name. At the end of the year the bookkeeper would be able to record on his patronage ledger, under the name of each patron, the total transactions of both kinds of business occurring during the year. It has been customary under the county-unit plan to keep the business of each elevator separate and apart from that of any other belonging to the group. For this reason the profit derived from the business of each of these elevators also can be determined.

Although it is usual to consider the profits of the organization as a whole when distributing patronage dividends under this arrangement, a condition sometimes has arisen which has been the subject of considerable discussion. By keeping each elevator's business entirely separate, in some instances the patrons of the different elevators have been paid their pro rata share of the profits of the elevator with which they did business. In some cases different elevators operating at a less relative cost per bushel have been able to pay a higher per bushel dividend than others in the same group. The following question has then arisen: Inasmuch as each patron is contributing to the prosperity of the county organization on a per bushel basis, from which it is assumed the same margin of profit has been taken, would it not be more equitable if the gross profits of the organization were pooled, the entire expenses deducted, and each patron paid his equal

pro rata share of the entire net profit, thus equalizing the rate of payment per bushel to each patron? The solution of this question rests upon the point of view which the cooperators maintain in relation to the purposes of cooperation. If they look upon the subject from a broad standpoint and consider themselves as members of the county organization first and of their local organization last, then they will feel that the rate of dividend payments should be equalized according to the transactions of the organization as a county unit. On the other hand, if the organization is not so closely united in sentiment nor in actuality, but is rather a group of organizations banded together for the mutual benefit of the separate elevators and not for an equal rate of benefit to the patrons, each patron will depend upon the prosperity of his local for the rate of return per bushel on his grain. His other transactions with the company would be on the same principle.

COUNTY UNIT OR DISTRICT REQUIREMENTS.

For accounting purposes the methods of doing business in the fourth and fifth classes of companies which operate elevators or warehouses exclusively would fall under three heads, two of which are operative under the county-unit plan. These may be defined as follows: Groups of elevators where the profits are determined for each elevator; groups of elevators where the profits are pooled in the treasury of the general organization; and groups of elevators shipping to a terminal elevator belonging to the company, where the grain is held for future sale and where grain from various elevators is mixed in the process of selling, thus losing the carload identity of the different original shipments.¹ Under the third group two divisions may be found. The first, wherein the various elevators ship all their grain to the terminal warehouse, and the second comprising those which ship partially to the terminal warehouse and sell the remainder of their output independently to outside parties.

Accounting methods suitable for the first two groups would be practically identical with those used under the county-unit plan except that the idea would have to be extended in accordance with the increased number of elevators participating. In considering the third group, there is the possibility of a difference of opinion over the basis of distribution, as previously cited—whether it should be upon an equal pro rata division of the net profits, considering the profits as belonging to the entire organization, or whether each elevator should receive back its pro rata share of the whole net

¹ The Farmers' Union operates terminal warehouses at various points in the Canadian Northwest which would fall under this plan.

profit, this to be distributed among its patrons. Independent sales fall outside the discussion of proration of general profits, because the profits from these accrue entirely to the elevator making the sale. If profits are pooled and the expenses of all the elevators participating are also shared on a common basis, the method of finding the rate for the division of the profits is merely a matter of dividing the profits by the number of bushels of grain handled by the entire group of elevators. If, on the other hand, the varying rates of expense incidental to operation in the different elevators and the various advantages in selling which have occurred during the year are taken into consideration, the division of profits then becomes much more complicated.

By compiling a formula which takes into consideration all the factors which go to make up the rate of profit, the amount of profit for each elevator can be determined, and this will allow a distribution of profits on varying rates to the patrons of the different elevators in accordance with the economic advantage of each separate station.

For purposes of illustration it will be assumed that in a certain organization there are five elevators, each operating on a different rate of expense, all shipping to the central organization, which, acting as their agent, disposes of the grain through its terminal warehouse. In such a case each elevator must keep its own books, so that it will know the amount of expense incurred and the number of bushels handled. At the end of the year, when the central organization has determined the total amount of profit, settlements will be made with the various locals according to the following table,¹ from which it will be seen that the average cost of operation per bushel is \$0.03.

	Bushels handled.	Elevator expense.	Share of profit for each ele- vator.	Individual expense per bushel.
Elevator A.....	500	\$25	\$40	\$0.05
Elevator B.....	500	30	35	.06
Elevator C.....	1,200	40	116	.0333
Elevator D.....	2,400	40	272	.0167
Elevator E.....	600	21	57	.035
	5,200	156	520	.....

The figures in this table are determined by the use of a formula which is derived from the combination of various items which must be taken into consideration when transacting the business under this arrangement. Before setting down the formula, the

¹ These figures are not taken from any firm, but are used merely for illustration.

meaning of the various letters comprising it are explained as follows:

- (*e*) Individual expense.
- (*c*) Cost of handling at each elevator per bushel.
- (*ac*) Average cost of handling per bushel for the total.
- (*b*) Number of bushels handled.
- (*p*) Average profit per bushel for the total.
- (*ip*) Individual profit for each elevator.

From this it will be seen that $\frac{e}{b}=c$ and $p-(c-ac)\times b=ip$. In other words, assuming in the above table that the average profit per bushel for the total was 10 cents, the formula in figures for each elevator, taking elevator A as an example, would be $\frac{25}{500}=0.05$, which is the per bushel cost of operating. The average cost is $\frac{156}{5200}=0.03$.

The formula for individual profit in figures would be as follows: $0.10-(0.05-0.03)\times 500=40.00$, which is the individual share of profit belonging to elevator A. The profit belonging to each of the other elevators is determined in a similar manner, and the total profit thus determined will be found to equal \$520, which is 10 cents per bushel on 5,200 bushels.

In order to adjust a plan of accounting and business practice to the needs of a large organization, it will be well to have a business and accounting expert go over carefully the present methods of business and make recommendations. This will mean the organization of an office staff competent to perform the work connected with the management of the business. The plans outlined in this bulletin, if put in operation under competent control, should insure the equitable distribution among the patrons of the earnings of elevator and warehouse companies.

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BULLETIN No. 372



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



May 16, 1916

COMMERCIAL PRODUCTION OF THYMOL FROM HORSEMINT (*MONARDA PUNCTATA*).

By S. C. HOOD,

Scientific Assistant, Drug-Plant and Poisonous-Plant Investigations.

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INTRODUCTION.

It has long been known that thymol is present in considerable quantity in the oil distilled from horsemint (*Monarda punctata*), but so far as the writer had been able to learn no attempt has been made to cultivate this plant for the commercial production of thymol. In 1907 horsemint was observed to occur in abundance as a common weed on the sandy lands of central Florida, and the preliminary examinations of the oil from the wild plants which were made at that time seemed to indicate that a promising commercial source of thymol could be developed by bringing this plant under cultivation and selecting for propagation types of plants best suited for oil production.

The leaf area of the wild plants is rather small, and the herb when harvested consists mainly of woody stems which yield little or no oil. The fresh entire herb gathered in Putnam and Volusia Counties, Fla., yielded from 0.12 to 0.20 per cent of oil, although in some samples the yield fell far below these figures, owing to the excessive proportion of stems. The content of total phenols in these oils ranged from 56 to 62 per cent, and it was found that the phenols consisted almost entirely of thymol.

The first problem, therefore, seemed to be to increase the leaf area and thus increase the yield of oil per acre. Accordingly, in 1910 a small plat of ground was set with plants grown from a mixed collection of seeds secured from wild plants in Volusia County. Of the first year's growth from this plat, 196 pounds of herb was distilled and yielded 0.17 per cent of oil. In the second year the yield of oil from plants grown on the same plat was 0.24 per cent. The content of total phenols in the oils was found to be 64 per cent.

A large number of variations in the plants were noted in 1910, and from these about sixty individual plants showing the various forms were selected for seed purposes. The seed from these plants was sown in 1911, but the resulting plants were not true to type. It was noted, however, that the variations fell into two general classes—dark and light plants—and that to a large extent these variations came true to type. The dark plants had much darker leaves, more serrate, and with a pronounced red color in the stems and branches. The light plants had larger leaves, lighter green in color, and with little or no red color in the stems and branches. There was also a greater tendency to the production of leaves in the light than in the dark type. From 34 tests which were made to show the relative yield of oil of these two types of plants the following average yields of oil were obtained: From the dark type, 0.40 per cent of oil, which contained 66 per cent of phenols; from the light type, 0.42 per cent of oil, with 69 per cent of phenols. The specific gravity, as well as the percentages of oil and of phenols in the oil, was found to be higher in the plants of the light type. Future seed selection was therefore carried on with this type.

In 1912 a further comparison was made between the light and dark forms and the results obtained were still more marked, but owing to weather conditions all samples showed a low yield of oil. The average of 36 tests was as follows: Dark type, 0.31 per cent of oil, which contained 65 per cent of phenols; light type, 0.40 per cent of oil, which contained 68 per cent of phenols. By continuing the selection of the light type of plants the yield of oil has been gradually increased, and in 1914 the herb from a plat of two-thirds of an acre yielded 0.44 per cent of oil, which contained 72 per cent of phenols, while in 1915 the average was 0.42 per cent of oil, containing 74 per cent of phenols.

During these years selection was also made to increase the size of the plants in order that the tonnage of herb per acre might be increased. This was also successful and a considerably increased yield was noted year by year. It is believed that at the present time the selection has been carried far enough to warrant the use of the improved form for the commercial production of thymol in the United States.¹

¹ The department has no supply of selected seed or plants of horsemint available for distribution.

CULTURAL METHODS FOR HORSEMINT.

PLANTING THE SEED.

The seed of horsemint matures in the Southeastern States during August and September and is ready to be gathered as soon as the calyx is dry and has assumed a dark-brown color. If left too long the largest and best seed will be lost and only the inferior seed will remain for collection. The seed can readily be gathered by hand by stripping off the entire heads, together with such leaves or bracts as remain on the stem. This material should be spread on a cloth or tight floor and as soon as it is thoroughly dry the seeds can be removed by rubbing through a sieve having 12 to 16 meshes to the inch, common window screening being about the right size. Further sifting and very gentle winnowing will remove most of the foreign material.

In the extreme Southeastern States, where the winters are free from severe frosts and snow, the best results are secured by planting the seed about the first of November in a carefully prepared seed bed. In order to avoid too thick sowing it is advisable to mix the seed with dry sand and sow the mixture evenly on the seed bed. A bed of 15 square feet will provide enough plants for an acre if properly planted.

After the seed has been sown, a layer of fine soil about one-eighth of an inch thick should be sifted over it and the bed well shaded by cloth. A good form of seed bed is that used by market gardeners in the South for raising celery plants. The soil should be kept moist, and as soon as the plants begin to come up the cloth should be removed. The seed will germinate in from six to ten days, and at two months from sowing the plants should be 2 inches high and ready for transplanting to the fields. If this work is done following a rain and the soil is in good condition no watering is necessary.

SOILS.

Horsemint occurs wild on light sandy soils and under cultivation has given the best results on this type of soil. It is essentially a lime-loving plant and its culture has not been successful on soils which were strongly acid, nor on heavy clays or low land where the drainage was poor or the amount of moisture excessive. The best results have been secured on rich, well-drained sandy loam, underlain with marl or clay at a depth of from 2 to 3 feet. Considering all the factors involved in the commercial production of this plant, it probably would be advisable to make plantings on light sands, such as the high pine lands of the Southeastern States. Horsemint occasionally occurs wild in dry fields on sandy soils from southern New York to Florida and westward to Wisconsin, Kansas, and Texas. It probably would thrive under cultivation wherever it is found growing wild, although its profitable production will depend upon local economic conditions.

CULTIVATION AND FERTILIZERS.

The plants should be set in the field in rows 3 feet apart and about 18 inches to 2 feet apart in the row. This will permit the use of horse cultivation as soon as the plants have become established in the field. The usual cultivation should be given until the plants are large enough to shade the ground and thus prevent the growth of weeds which might injure the crop at harvest time.

In 1912 a series of fertilizer experiments was carried out on 36 plats. It was found that although certain special methods of treatment had a marked effect on the percentage of yield of oil and of thymol in the oil, the greatest yield was obtained by promoting the growth of the plant and thus securing the largest possible yield of herb per acre.

Acid phosphate gave more herb and a higher percentage of oil than did bone black, and calculated on the yield of thymol per acre the ratio was as 2 to 1 in favor of the acid phosphate. Nitrate of soda did not give as satisfactory results as sulphate of ammonia. The use of an organic source of nitrogen in the complete formula did not give as good results as when all the nitrogen was applied in the form of sulphate of ammonia. There was a slight difference in favor of the application of the potash in the form of sulphate. The best results were obtained by the use of a complete fertilizer having the following analysis: Nitrogen, 4 per cent; phosphoric acid, 6 per cent; potash, 10 per cent. With this fertilizer made from sulphate of ammonia, acid phosphate, and sulphate of potash, 600 pounds per acre should be sufficient to produce a good crop, and less could be used on land having a fair degree of fertility.

It has been found advisable to make the application of fertilizer after the plants have become established in the field, but care should be taken to prevent injury to the leaves by the fertilizer.

The average composition of a number of samples of horsemint made both before and after distillation is shown in Table I, the results being calculated on the basis of dry material.

TABLE I.—*Composition of horsemint before and after distillation.*

Time of analysis.	Ash.	Nitrogen, as ammonia.	Phosphoric acid, as P ₂ O ₅ .	Potash, as K ₂ O.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Before distillation.....	7.73	1.46	0.58	2.38
After distillation.....	8.17	1.33	.54	2.12

Taking as a basis the average composition of the herb before distillation and allowing 25 per cent as the average quantity of dry matter, the quantity found in a large number of determinations, it

appears that a crop of 10,000 pounds will remove from one acre of land the following quantities of nutrient materials: Nitrogen, as ammonia, 38.5 pounds; phosphoric acid, as P_2O_5 , 14.5 pounds; and potash, as K_2O , 59.5 pounds. The materials removed from the soil could be replaced by the use of 800 pounds per acre of fertilizer having the following composition: Nitrogen, as ammonia, 4.81 per cent; phosphoric acid, as P_2O_5 , 1.81 per cent; and potash, as K_2O , 7.43 per cent.

Since some disposal must be made of the distilled herb it is probable that this material if returned to the soil would restore most of the nutrient materials removed and at the same time add vegetable matter to the land. It is advisable, however, to compost this material and to apply it to the field only after it is well decomposed. The exhausted material has been found to contain an average of 50 per cent of water; and if proper allowance is made for the water content a ton of this material would yield the following quantities of nutrient materials: Nitrogen, as ammonia, 13.3 pounds; phosphoric acid, as P_2O_5 , 5.4 pounds; and potash, as K_2O , 21.2 pounds.

HARVESTING.

In harvesting the crop excellent results were secured by the use of a 1-horse mowing machine, which was made adaptable for the purpose by placing shoes under each end of the cutting bar, so that the plants were cut about 6 inches above the ground. As soon as it is cut the herb should be gathered and hauled to the distilling plant, since it has been found that by allowing the plants to dry in the field there is considerable loss of oil. A large loss of leaves also results, owing to their rapid drying and shattering off in handling. Care must be taken in harvesting that the rooted layers about the plant are not torn loose; otherwise, a large percentage of the plants left in the field will die. The lower branches of the plant which spring from the stems near its base grow downward and strike root by natural layerage, and since in a large number of cases the old root dies after the first year the plant is perpetuated by these layers. In light soils these roots are easily torn loose and the death of the plant results. On this account the use of a rake for getting up the cut herb is undesirable, and forks should be used for that purpose.

Considerable work, extending over a period of several years, has been done in order to determine the proper time for harvesting the herb and also to ascertain the yield of oil and thymol at the different stages of growth. In 1911, 16 tests were made with plants in the budded stage and a like number with plants in full flower, to determine the percentage of yield of oil and thymol in these two stages. The average yield was as follows: In the budded stage, 0.36 per cent of oil, with 64 per cent of total phenols; from the plants in full flower,

0.33 per cent, with 67 per cent of phenols. In order to gather further data on this point tests were made in 1912 with plants in various stages of growth harvested from measured areas. The results obtained are summarized in Table II, which also shows the same results reduced to the basis of yield per acre.

TABLE II.—*Yield of oil and total phenols from horsemint at different stages of growth.*

Stage of growth.	Weight of herb distilled.	Actual yield.		Yield per acre.		
		Oil.	Total phenols.	Herb.	Oil.	Phenols.
Plants just beginning to send up flower stalks.....	Pounds. 453	Per cent. 0.34	Per cent. 72	Pounds. 9,690	Pounds. 32.94	Pounds. 23.05
Budded stage.....	506	.30	76	10,590	31.77	24.14
Full flower.....	1,403	.24	74	10,000	24	18.48
Flowers fallen.....	352	.18	74	8,500	15.30	10.82

From these results it will be seen that the highest yield of phenols is secured in the budded stage and that the loss is very rapid as the flowering period advances. Since, however, the difference is but slight between the first and second stages, it is advisable with a large acreage to begin harvesting about the time the flower stalks begin to shoot up; otherwise, it may not be possible to harvest part of the area until the flowering stage is well advanced, and thus loss will result.

DISTILLATION.

Distillation of the horsemint herb is carried on by the usual methods in practice for distilling such volatile oils as peppermint and spearmint. A retort made of wood, galvanized iron, or boiler iron is used to contain the herb. This retort is connected to a condenser by a pipe of proper size from the top of the retort. The condenser may be of the worm type, such as is used in the distillation of turpentine, or of the tubular type, with flues similar in arrangement to a vertical boiler. Steam from a boiler is admitted to the retort at the bottom and passing through the herb enters the condenser, where the mixed vapors of steam and oil are cooled by a water jacket. The mixture of water and oil flowing from the condenser should be collected in a receptacle having a side tube entering the container at the bottom and bent up so that the outlet is only about 2 inches below the top of the container. This will allow the water to be discharged through the side tube, while the oil is retained as a layer on top. It has been found advisable to retain the water which flows from the oil receiver, in order to recover the oil dissolved in it, since this recovered oil is very rich in thymol.

In 1911, 4 gallons of this water was allowed to stand for several days until it was perfectly clear and all the oil globules were removed. When redistilled a yield of 0.114 per cent of oil was secured, containing

95 per cent of total phenols. In 1912 a total of about 35 gallons of water was distilled and a yield of 0.05 per cent of oil was secured, having 98 per cent of phenols. The quantity of oil which is dissolved in the water under the usual methods of distillation is strikingly shown by the results for 1914, which are summarized in Table III.

TABLE III.—Quantity of oil recovered from the water as compared with that obtained from horsemint.

Weight of herb.	Oil from the herb.	Oil recovered from the water.
	<i>Pounds.</i>	<i>Pounds.</i>
441 pounds.....	1.6	0.20
395 pounds.....	1.8	.19
302 pounds.....	1.2	.12

For the year 1914 the oil recovered from the water contained 90 per cent of phenols.

From these results it will be seen that the redistillation of this water is practicable and will add about one-seventh to the quantity of oil secured from the herb. This redistillation can readily be accomplished by collecting the water in a suitable receptacle, and when a sufficient quantity has accumulated it can be run into the retort and distilled in the same manner as the herb, or the water secured can each time be added to the next charge of herb and distilled with it.

By passing the fresh herb through a fodder cutter or shredder it is possible to distill a larger quantity at a time, but it in no way hastens the distillation process; on the contrary, it hinders somewhat the unloading of the material if it is removed from the top of the retort. If the retort is emptied from the bottom, as is customary in the larger distillation plants, it is practicable to cut the herb, since it much facilitates the dumping. These are points which the distiller must decide according to his special conditions and the scale of his operations.

The size and number of the retorts used will depend upon the quantity of material to be distilled during the season. If the herb is cut before distillation, about 100 pounds can be contained in each 7 cubic feet of retort space. A retort 6 feet in diameter and 8 feet high would contain about 3,200 pounds of the cut herb, or about half that quantity of the whole herb.

As soon as it is distilled the oil should be freed from water in a separatory funnel and shaken with a small quantity of anhydrous calcium chlorid to remove the last traces of water and to prevent turbidity. It can then be stored until wanted for refining. It is preferable to use glass containers if the oil is to be stored for any length of time, since contact with iron or tin will darken the oil and make the refining more difficult.

EXTRACTION OF THE THYMOL.

The oil of horsemint distilled from plants grown in Florida consists of phenols to the extent of 70 to 80 per cent, and these phenols consist almost entirely of thymol, there being present also very small quantities of carvacrol. The nonphenol portion of the oil consists largely of cymene, which acts as a solvent for the thymol and prevents complete crystallization. It is therefore necessary to separate these two compounds as a preliminary step in the extraction of the thymol.

Since the two main constituents have a widely different boiling point, cymene boiling at 175° to 176° C. and thymol at 232° C. under normal pressure, almost complete separation can be secured by fractional distillation. The method devised for the separation is as follows: The crude oil is distilled in a proper retort of copper, which is fitted with an efficient fractionation column, the one used in these experiments with the best results being the Hempel form. Distillation is carried on slowly and the portion of the oil coming over below 215° C. is set aside. The temperature is then raised slightly and the fraction distilling over between 215° and 240° C. is secured. The residue in the retort is a thick, tarlike mass and so far as known is of no value.

Practically all the thymol is now contained in the second fraction, which consists of a rather heavy, slightly yellow liquid. The quantity of thymol contained in the first fraction should not be large if the process has been carried on carefully, but may run as high as 25 to 30 per cent. This fraction is now redistilled under the same conditions as before, and the second fraction secured between 215° and 240° C. is placed with the first one secured at this temperature and the residue discarded.

The total fractions secured between 215° and 240° C. are allowed to cool in a shallow container and a small crystal of thymol is added to start crystallization. Within a few minutes a heavy crop of crystals will be secured. After standing over night the crystals are separated from the mother liquor by means of a centrifuge, and the crystals are washed with water while the centrifuge is running at full speed and then dried by continued running of the centrifuge for three to five minutes.

If cooled in a freezing mixture or by setting in a cold place, the mother liquor will deposit another crop of crystals, but if a very large quantity of mother liquor is present it indicates that a considerable portion of the lower boiling fractions was not removed. It should, therefore, again be distilled in the same manner as before and the fraction secured between 215° and 240° C. should be treated in the manner previously described.

A sample of 28 pounds of horsemint oil, showing on assay 72 per cent of total phenols, was worked up by this process and 18 pounds of pure thymol was manufactured from it, which is equal to a commercial yield of 64.3 per cent of thymol from the oil. When made by this process a perfectly white crystalline product was secured; 15 pounds of thymol made by this process in 1915 was sold to the trade at a high price. Should a slightly yellow product be secured a second distillation would be required. It has been found, however, that with ordinary care a high-grade product will result from the first distillation. By this process three residues are secured in small quantities, the lower boiling fraction consisting largely of cymene, the mother liquor from the last crystallization of phenols, and the tarlike residue remaining in the retort after the last fraction has been removed. Work is at present under way looking to the utilization of these residues.

In order to provide an inexpensive and practical apparatus for the extraction of thymol from the oil on a moderate scale, the following apparatus has been devised:

(1) A flask 12 inches in diameter and 16 inches high, made of about 30-ounce copper. The top is brought to a short neck 3 inches in diameter and reenforced by a brass band half an inch wide and one-quarter inch thick, turned edgewise to form a ring and brazed to the neck, forming a flange. The seam in the flask must be brazed, since the temperature of the boiling oil is above the melting point of solder.

(2) A column 22 inches long of 3-inch thin-walled brass or copper tubing. The lower end is fitted with a brass ring of the same size and in the same manner as the neck of the flask and with it forming a flange joint. In the lower end of the column is brazed a brass or copper disk, set at an angle of about 30°. The top of the tube is covered with a cap, brazed on, and in the center is set a piece of three-fourths inch brass tubing, about 1 inch long, forming a neck, into which a cork can be fitted. About 4 inches below the top a side tube of 1-inch brass tubing is brazed in a slight angle downward. This tube should be about 20 inches long and at the free end should have an elbow which just fits into the end of the condenser.

The condenser is of copper, $4\frac{1}{2}$ inches in diameter and about 20 inches long, and consists of an outer cylinder with a head at each end. Running through from one head to the other are seven quarter-inch tubes of copper or block tin. A side tube at the bottom and one at the top serve for the inlet and outlet of the cooling water, which moves from the bottom upward about the flues. To each end is soldered a brass collar 2 by 2 inches, which serves as a chamber about the ends of the flues. This slips over the enlarged end of the delivery tube at the top to form a fairly tight joint, while over the bottom collar is placed a funnel-shaped nozzle to collect and deliver as one stream the liquids which run down the flues. The entire condenser can be made with soldered joints, since the water jacket will prevent melting. A complete condenser can be bought from dealers in chemical and pharmaceutical apparatus or can be made at small expense by any good coppersmith.

The apparatus should be set up with the flask supported over a good flame which can be easily regulated, such as that from a large oil burner or from a gas or gasoline burner. The condenser is supported in a vertical position and the bottom side tube connected with a supply of cold water. The column is filled to within 1 or 2 inches of the side tube with glass beads one-half inch in diameter or with small unpainted baked clay or glass marbles. The hole in the top of the column is fitted with a tight cork, through the center of which a tube is placed just large enough to admit a common chemical thermometer graduated in centigrade degrees, with the scale reading from 100 to 300. This thermometer should be placed through the cork so that the bulb is just opposite the side tube. The flask is then filled a little more than half full of the horsemint oil and the joint between the flask and the column made tight with a leather gasket and clamp, or it may be secured by the use of a ground-joint brass union, one half of which is brazed to the neck of the flask and the other half to the column. This does away with the use of the gasket, which must be frequently renewed.

An apparatus of the size described will take 15 pounds of oil at a charge and in a day work up 75 to 100 pounds of oil. The cost of construction would be about \$50.

YIELD PER ACRE.

During the past five years areas up to 1 acre in extent have been grown on various soils and as far as possible under actual commercial conditions. The results thus far secured show that an average of 20 pounds of oil per acre from first-year plantings may be regarded as a fair crop, although the test areas have sometimes shown a greater quantity. In succeeding years the yield should be at least 30 pounds of oil per acre, and under good conditions 40 pounds may be expected. Assuming the average phenol content of the oil to be 70 per cent, a figure which is somewhat below the average found for five years, and using the process of manufacture previously described, there may be expected for the first year a yield of 12.86 pounds of pure thymol per acre and for the succeeding years, 19.29 pounds per acre. Taking \$2 per pound as the average price of thymol for a period of years, there would be a gross return per acre the first year of \$25.72 and for each succeeding year, \$38.58. In addition to this there should doubtless be added a small amount for the value of the residues, which at the present time has not been determined.

COMMERCIAL PROSPECTS.

For many years the commercial source of thymol has been chiefly the oil of *Carum ajowan* derived from ajowan seed, which is grown in the region of northern India and shipped to northern Europe, where

the thymol is extracted. Thymol is extensively used in medicine and serves as an antiseptic. It is used internally for the treatment of certain conditions and is the basis of a number of important pharmaceutical compounds.

The importation of thymol for the 10 years 1906 to 1915, inclusive, as compiled from the weekly report of "Imports for consumption" in the Oil, Paint, and Drug Reporter, is shown in Table IV.

TABLE IV.—*Importation of thymol for 10 years, 1906 to 1915, inclusive.*

Year.	Imports.	Year.	Imports.
	<i>Pounds.</i>		<i>Pounds.</i>
1906.....	2,983	1911.....	3,576
1907.....	4,753	1912.....	2,930
1908.....	5,010	1913.....	6,620
1909.....	10,336	1914.....	18,048
1910.....	3,352	1915.....	2,031

From these figures it would seem that the annual consumption of thymol in the United States is sufficiently great to warrant a small industry for its production when carried on in connection with the distillation of other volatile oils.

The estimates of the cost of production summarized in Table V are based on the conditions existing in central Florida, where actual field tests have been made for several years. Such items as land rent, taxes, etc., are not included, nor has any allowance been made for depreciation, upkeep, or interest on the distilling plant, since it is doubtful whether the profits are sufficient to warrant the starting of an independent industry in thymol production if all the costs of equipment for the year are to be charged to this item alone.

TABLE V.—*Estimates of cost per acre for producing horsemint.*

Expenses.	First year.	Each succeeding year.
Growing plants in seed bed.....	\$1	.....
Fitting land.....	3	.....
Planting in field.....	3	.....
Fertilizer.....	8	8
Cultivation.....	2	1
Harvesting and distilling.....	6	10
Total.....	23	19

In these estimates it has been assumed that the residues on removing the thymol from the oil will at least pay the cost of manufacture. It has been determined that a plantation of horsemint will not need to be replanted oftener than once in five years, and under average soil conditions it is possible that it will continue to give a full yield for a still longer time. Consideration should also be given to the

fact that after the first year a material reduction can be made in the cost for fertilizers if the distilled herb after being well decomposed is returned to the soil, since, as has been previously stated, this will restore much of the nutrient materials removed by the crop. The estimated returns show that a profit of about \$16 per acre may be expected as an average for a 5-year period.

It has been shown that horsemint can be grown on the lighter types of soil at comparatively little expense, and as the cost of transportation for the finished product, thymol, is very low, it would seem that the production of this crop might be profitable when grown in connection with other oil-yielding plants for which a distilling apparatus is required.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 373

Contribution from the Office of Public Roads and Rural Engineering, LOGAN WALLER PAGE, Director.



Washington, D. C.



August 25, 1916

BRICK ROADS.¹

By VERNON M. PEIRCE, *Chief of Construction*, and CHARLES H. MOOREFIELD, *Senior Highway Engineer*.

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INTRODUCTION.

A clay product closely resembling our present-day brick was among the earliest materials used for paving streets and roads. The first brick pavement constructed in this country, however, dates back no further than 1872, and to Charleston, W. Va., belongs the distinction of having been the first American city to employ brick for paving.

For a number of years after being introduced into this country the use of paving brick was principally confined to city streets, and, owing to the frequent inferiority in the quality of the brick and lack of care in construction, very few of the early pavements proved satisfactory. Even now, after the experience of 40 years has demonstrated that it is entirely practicable to construct satisfactory brick pavements when proper care is exercised, and that much waste results from the use of poor materials or faulty construction, instances can frequently be found where comparatively new brick pavements have wholly or partially failed from causes which might easily have been prevented. (See Pl. I and Pl. II.)

Country roads paved with vitrified brick are becoming quite common in many of our States. The principal advantages which brick

¹ A revision of Department Bulletin 246, entitled " Vitrified Brick Pavements for Country Roads."

roads possess may be stated briefly, as follows: (1) They are durable under practically all traffic conditions; (2) they afford easy traction and moderately good foothold for horses; and (3) they are easily maintained and kept clean.

The principal disadvantage is the high first cost. The defects which frequently result from lack of uniformity in the quality of the brick or from poor construction are usually to be traced indirectly to an effort to reduce the first cost or to a popular feeling that local materials should be used, even when of inferior quality.

This bulletin purposes to furnish information relating to the construction of brick roads and to supply suggestions for aiding engineers in preparing specifications under which such work may be satisfactorily performed. One of the most essential features of the construction of brick pavements is the selection of the brick, since the success or failure of such pavements depends to a large extent on the character of the material used. In order that the significance of the varying physical characteristics observed in brick manufactured under different conditions may be more readily understood, a brief discussion of the raw materials and processes used in the manufacture of brick will be given.

THE RAW MATERIALS.

Paving brick are made from shales and fire clays. The "lean or less refractory varieties of these materials, which are found in the carboniferous deposits broadly distributed throughout the United States, are best adapted for this purpose.

Shales frequently occur in such quantity and are so located that they may be readily excavated by means of a steam shovel or other mechanical device. Occasionally the deposits are comparatively thin and underlie other material, making it necessary that they be mined. Fire clays are usually found interstratified with coal deposits which may or may not be workable, and must, therefore, generally be mined. The principal difference between fire clays and shales, in so far as the manufacture of brick is concerned, is essentially a difference of color in the finished product. The shales always contain iron in some form, and brick made of shale are usually red. Fire clays are free from iron and should produce a light-colored brick. Some low-grade fire clays, however, may be darkened by certain firing conditions too complicated to be discussed in detail here.

Shales and fire clays as they occur in nature are not always well suited for use in the manufacture of paving brick, but must frequently be subjected to some modifying treatment before being used. In general, deposits of these materials occur in layers or strata, and the different strata are almost always slightly dissimilar in both

physical and chemical composition. By carefully mixing the materials from different strata or from different parts of the bank, therefore, a resulting material of the desired character may usually be obtained. But it not infrequently happens that in order to secure the best results sand or surface clay must be added in an amount depending on the relative "leanness" or "fatness"¹ of the material used. In this connection it may be noted, also, that a chemical analysis of a given fire clay or shale does not necessarily indicate its fitness or unfitness for paving brick. The reason for this is that the quality of the brick after "firing" is no less dependent on the physical arrangement of the minerals than on the chemical composition of the material.

THE MANUFACTURE.

The general processes of manufacture are the same for both fire clays and shale. The raw material in either case is crushed to comparatively small fragments and conveyed by some convenient means to a grinding machine, known in the industry as a dry pan. Briefly, this machine consists of a solid iron plate, approximately 5 feet in diameter, surrounded by a perforated iron surface about 2 feet wide. Outside the perforated surface is a rim some 15 inches in height which serves to prevent the material from escaping otherwise than through the perforations. Upon the solid plate rest two massive crushers or mullers, each weighing from $2\frac{1}{2}$ to 3 tons. The pan is revolved rapidly, causing the mullers to rotate by friction. The material is ground between the mullers and the plate and thrown out by centrifugal force toward the rim, where it escapes through the perforated surface into an elevator, by means of which it is conveyed to the screens.

The particles too large to pass the screens, which should not exceed three-sixteenths inch in mesh, are returned to the dry pan, while the screened material is passed to the mixing machine or pug mill by means of conveyers. In the pug mill, water is admixed with the clay to form a stiff mud, which is fed continuously into the brick machine proper.

The brick machine is an extremely heavy mechanism. It consists essentially of an auger or propeller conveyer, a tapering barrel, and the die or former. The material is forced by means of the auger conveyer into the tapering barrel, which terminates in the die, and issues from the die in a solid column under heavy pressure. For "side-cut" brick this column is approximately $4\frac{1}{2}$ inches by 10 inches in cross section, and the brick are formed by cutting through the column, by means of an automatic device, at intervals of about $3\frac{1}{2}$

¹ "Leanness" and "fatness" refer respectively to the lesser or greater amount of silicate present in the material.

inches. For "end-cut" brick the column has a cross section approximately 4 inches by $4\frac{1}{2}$ inches and is cut into sections about 10 inches long.

In order that the successive courses in a brick pavement may be uniformly spaced, it is necessary that suitable lugs be formed on the brick either at the time they are cut, or later by means of re-press molds. Special shapes, such as nose brick for use next to car tracks, and hillside block, which have one side thicker than the other and which are used on steep grades in order to give the pavement a rough surface, may be made either by special die or special re-press molds.

The next step in the process of manufacture consists in drying the brick. In a properly systematized plant the brick are stacked upon drier cars as they leave the presses in such manner as to permit a free circulation of air between them. The loaded cars are immediately run into a tunnel drier, the temperature of which is maintained at about 100° F. at the entering end. As cars containing "green" brick enter one end of the tunnel, which is usually more than 100 feet long, other cars containing dry brick are being removed at the opposite end. Air circulation in the drier is effected by means of fans or high stacks. During drying the brick lose an amount of moisture equivalent to from 15 to 20 per cent of their own weight.

The brick leave the drier ready for burning, which is the last and undoubtedly the most important step in the process of manufacture. Upon the burning depends largely the quality of the finished product, and it requires the greatest skill so to regulate the temperatures and firing periods as to obtain the best results from a given material. Experience alone can demonstrate the manner in which the burning must be modified in order to suit varying sets of conditions. The kilns in which the burning is done are made of brick and are provided with numerous furnaces. The brick are placed in the kilns so as to permit a free circulation of the gases of combustion and the heated air.

PHYSICAL CHARACTERISTICS.

GENERAL REQUIREMENTS.

Paving brick should be uniform in size, reasonably perfect in shape, free from ragging due to friction in the die, and from deep kiln marks caused by impressions from overlying brick in burning. They should be tough in order to resist crushing, hard in order to resist abrasion, and uniformly graded in order that the pavement may wear evenly. Each brick should be homogeneous in texture and free from objectionable laminations or seams. Fire cracks, caused by too rapid firing, should be limited in number and extent, and the entire brick should be vitrified and should contain neither unfused nor glassy spots.

COLOR.

The color is a valuable guide in inspecting brick from the same plant, but it is of little importance when the brick to be compared are from different factories. For brick manufactured from a particular raw material the color indicates, in a measure, the temperature to which they have been subjected, provided they have been burned under identical conditions. Ordinarily, the darker the color the higher the temperature, and, presumably, the better the brick. The surface color of brick may be very misleading, however, and the color of the interior should be used in making comparisons.

SPECIFIC GRAVITY.

The specific gravity of paving brick was formerly considered of importance in judging their fitness for use in pavements. But it has since been generally conceded that a knowledge of the specific gravity is of comparatively little value. The specific gravity of shale brick is ordinarily between 2.20 and 2.40, and of fire-clay brick between 2.10 and 2.25.

ABSORPTION.

The absorptive power of brick, like their color, is a matter of very slight importance, except for comparing specimens manufactured under identical conditions. It is true that the porosity of the brick increases with the power of absorption, but it is very doubtful if any paving brick possessing an objectionably high absorptive power could pass even a very casual inspection. In other words, a high degree of porosity always manifests itself in other ways more clearly than in the ability of the brick to absorb water.

CRUSHING STRENGTH.

The crushing strength of good paving brick varies from 10,000 pounds to 20,000 pounds per square inch when the load is applied uniformly over the entire top surface of the test specimen, and may be much greater if the area over which the load is applied is less than that of the top surface. Since paving brick in use are seldom required to withstand a pressure of more than about 2,000 pounds per square inch, and since inferior brick may possess relatively very high resistance to crushing, a knowledge of the crushing strength is clearly of little value in comparing the relative excellence of different makes of brick. It is, therefore, usually considered unnecessary to specify a definite requirement as to the crushing strength of paving brick.

TESTING THE BRICK.

Definite methods of testing paving brick have been in general use for only a comparatively few years and have only recently undergone a pronounced change. The object of all tests is to determine whether

or not a given quality of brick is suitable for use in constructing pavements and to furnish a basis for comparing different classes of brick. The methods have, therefore, been repeatedly changed, not only in order to make the results obtained indicate more definitely the quality of the brick, but also with a view to establishing uniformity, so that results obtained in different laboratories may be intelligently compared. A discussion of the most important tests follows in more or less detail.

FIELD TEST.

The general appearance of a paving brick is, to an experienced eye, a valuable indication of its quality and will frequently suggest the advisability of applying routine tests to some particular part of a shipment. Unfortunately the knowledge gained from experience with one kind of brick can not be safely relied upon in inspecting other brick made by a different process or from a different class of raw material. A further limitation to this method of testing lies in the fact that the results obtained do not admit of numerical evaluation, and can not, therefore, be very accurately described. This test is nevertheless valuable, and since no apparatus other than a hand hammer is needed, it can always be employed.

The test consists simply in making a careful inspection of the brick individually and collectively. The size is tested by making measurements, the shape by arranging a number of brick in the order in which they are intended to be placed, and the quality by an examination of both the exterior and interior of a number of samples.

TRANSVERSE TEST.

The transverse strength of a brick is determined by supporting it upon two knife edges and applying a load on the opposite side and midway between the supports by means of a third knife edge. The load is gradually increased until rupture occurs, and the result of the test is expressed in terms of the ratio $\frac{3Pl}{2bd^2}$, called the modulus of rupture. In the above ratio P represents the breaking load in pounds, while l , b , and d represent, respectively, the distance between supports, the breadth of the specimen, and the depth of the specimen, all measured in inches.

The modulus of rupture for good paving brick usually lies between 2,000 and 3,000 pounds per square inch, and frequently varies considerably even with carefully selected specimens which have been manufactured under identical conditions.

RATTLER OR ABRASION TEST.

The rattler or abrasion test is undoubtedly the most important of the tests made on paving brick at present. In making this test the

specimen brick are subjected to destructive influences very similar to those encountered in actual service, and the results obtained, therefore, indicate very closely the effect which traffic may be expected to produce on a pavement constructed of similar brick. The methods of making the test, of which there were formerly a great many, have undergone repeated changes in order that service conditions may be more nearly approached, and also in an effort to bring about uniformity, so that the results obtained may be of the greatest possible scientific value. The method which is now proposed by the subcommittee on paving brick of the American Society for Testing Materials may be briefly described as follows:

The apparatus necessary for making the test, ordinarily called the rattler, consists of a 14-sided barrel of regular polygonal cross section supported on a suitable frame and fitted with the necessary driving mechanism. The staves, each of which forms a side of the barrel, are made of 6-inch 15.5-pound structural steel channels 27½ inches long. These staves are double bolted to the cast-iron heads of the barrel, which are provided with slotted flanges for holding the bolts. Cast-iron wear plates are bolted to the inside of the barrel heads. The inside diameter of the barrel is 28¾ inches.

In this barrel is placed what is known as the abrasive charge. This charge consists of two sizes of cast-iron spheres having respective diameters of 3¾ inches and 1⅞ inches and weighing, respectively, 7.5 pounds and 0.95 pound when new. Ten of the larger spheres are used, and the number of the smaller spheres is made such that the weight of the entire charge will approximate 300 pounds. The individual larger spheres are discarded whenever their weight falls to 7 pounds or less and the smaller spheres when they become sufficiently worn by usage to pass through a circular opening having a diameter of 1¼ inches.

The test is made by placing a charge of 10 dry brick in the barrel, together with the abrasive charge, and then revolving the barrel 1,800 times. The number of revolutions per minute is not permitted to fall below 29½ nor to exceed 30½, and the operation is made continuous from start to finish.

The results of the test are reckoned in terms of the loss in weight sustained by the brick, and this loss is expressed as a percentage of the original weight of the brick tested. In determining the loss in weight, no piece of brick which weighs less than 1 pound is considered as having withstood the test.

Good paving brick will ordinarily lose from 18 per cent to 24 per cent of their original weight in the rattler test, and specifications concerning this loss should be prepared with a view to the character of the traffic for which the pavement is designed.

It is also advisable to require a minimum as well as a maximum percentage of loss which any specified sample of the brick may sustain. This is done in order to insure against too much variation between the softest acceptable brick and the hardest brick which may be supplied.

CONSTRUCTION.

PREPARING THE ROADBED.

In forming a roadbed upon which a brick pavement is to be constructed, the essential features to be considered are (1) thorough drainage, (2) firmness, (3) uniformity in grade and cross section, and (4) adequate shoulders.

Thorough drainage can be secured for any particular road only by means of a careful study of the local conditions which affect the accumulation and "run-off" of both the surface and ground water. These conditions vary considerably even in the same locality, and no set of rules can be given which would cover all cases. For example, the material composing the roadbed may be springy, and in this case tile underdrains will probably be necessary. On the other hand, extremely flat topography may make it necessary to elevate the grade considerably above the surrounding land. The nature of the soil, the topography, and the rainfall must all be considered if a system of drainage is to be planned properly.

The second requirement, firmness, can be secured only after the road has been properly drained. Soils which readily absorb moisture can not be properly drained in wet weather and should not be permitted to form a part of the subgrade. In order that the subgrade may be unyielding, it is also necessary that the roadbed be thoroughly compacted. In forming embankments the material should be put down in layers not over 8 inches thick, and each layer should be thoroughly rolled. In excavation care should be exercised, if the material is earth, not to permit plows or scrapers to penetrate below the subgrade. The subgrade in both excavation and embankment should be brought to its final shape by means of fine grading with picks and shovels and rolling.

When completed the subgrade should be uniform in grade and cross section; otherwise the foundation must be made unnecessarily thick where depressions occur, in order that its grade and cross section may be uniform and its thickness not less at any point than that required. The subgrade should be repeatedly rolled and reshaped until the desired shape is secured. If curbs are constructed independent of the base they should be set before the final finishing, in order that they may be made to serve as a guide for this work.

The shoulders should never be less than 4 feet wide and should consist of some material which compacts readily under the roller and

does not readily absorb water. Not infrequently one of the shoulders is made sufficiently wide to form an earth roadway parallel to the brick pavement. Such an arrangement serves to relieve the pavement of considerable traffic during favorable seasons and also affords some advantage to horse-drawn traffic. The general method of constructing shoulders for brick roads is not essentially different from that employed for other types of pavements.

CURBING.

Brick pavements, as generally constructed, should be supplied with strong, durable curbing, both on the sides and at the ends. Otherwise the marginal brick will soon become displaced by the action of traffic, and their displacement will, of course, expose the brick next adjoining, so that deterioration might eventually spread over the entire pavement. Properly constructed curbing, on the other hand, will hold the pavement as in a frame and enable the brick to present their combined resistance to the destructive influences of traffic.

Satisfactory curbs may be constructed of stone, Portland cement concrete, or vitrified clay shapes made especially for this purpose. Wood has also been used for curbs to a limited extent, but when it is considered that the life of a brick pavement under ordinary conditions should far exceed the life of any wood curb which might be devised, the economy of employing a more durable material is readily apparent.

Stone curbing may be made from any hard, tough stone which is sufficiently homogeneous and free from seams to admit being quarried into blocks not less than 4 feet long, 5 inches thick, and 18 inches deep. On account of their ordinarily homogeneous structure, granite and sandstone are probably more used for curbs than any other kind of stone.

All stone curbing should be hauled, distributed, and set before the subgrade is completed. The individual blocks should be not less than about 4 feet long, except at closures, and should ordinarily have a depth of from 16 to 24 inches, depending on soil conditions and on whether the curb is to project above the surface, forming one side of the gutter. The neat thickness need never be greater than 8 inches and, where the traffic conditions are not severe and the quality of the stone is good, a thickness of 6 inches will ordinarily prove satisfactory. Stone curb should always be set on a firm bed of gravel, slag, or broken stone, not less than 3 inches thick, or on unusually firm earth, and should be provided with a backing of the same material on the shoulder or sidewalk side. Figure 1 shows a typical stone curb in place.

Where suitable stone is not readily available or when from any cause the cost of stone curbing would prove excessive, a curb con-

constructed of Portland cement concrete may frequently be advantageously used. Concrete curbs may be constructed alone or in combination with either a concrete gutter or a concrete foundation. When constructed alone they should have approximately the same cross-sectional dimensions as stone curbs and should be constructed in sections about 8 to 10 feet in length. Figures 2, 3, and 4 show the three common types of concrete curbs.

Vitrified clay curbing should be set in much the same manner as that described for stone curbing. The principal additional requirement is that, since vitrified clay is a lighter material than stone and the curb sections are ordinarily shorter, the bedding must be made correspondingly more secure in order to prevent displacement.

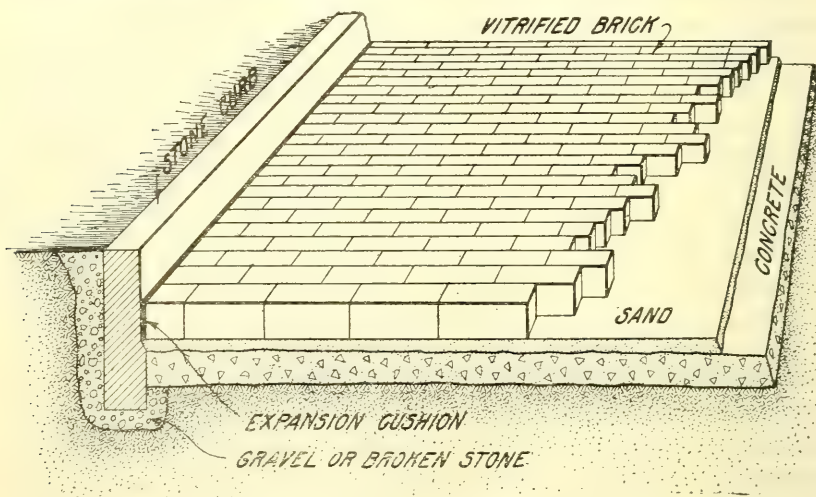


FIG. 1.—Proper method of constructing stone curb.

OPRRE 8994

Several sections of brick pavement in which curbs were altogether omitted were constructed during 1915 in the State of Illinois. The methods employed in constructing these pavements, which are designated "monolithic," are described on page 21.

THE FOUNDATION OR BASE.

A firm, unyielding foundation is one of the most essential features of a brick pavement. This fact can be more readily appreciated when it is considered that the surface of a brick pavement is made up of small individual blocks, any one of which might be easily forced down, causing unevenness in the surface, if the foundation were poor; and since the ability of the pavement to resist wear depends very largely on the smoothness of the surface, every reasonable precaution should be taken to prevent any unevenness from developing. The

fact that more brick pavements have failed on account of defective foundations than from any other cause should never be lost sight of by those planning and supervising this class of work. Plate I shows typical illustrations of what is likely to occur whenever this feature of the work is neglected. Both of the roads here illustrated were comparatively new, but failed when subjected to heavy motor-truck traffic. The one shown in Plate I, figure 1, had a rolled gravel foundation constructed under inadequate specifications and poor inspection, while in the other case a 4-inch concrete foundation was specified, but an inspection made after failure revealed that the concrete was of an inferior quality and that its thickness was generally less than that required by the specifications.

The proper type of foundation or base depends largely on the material composing the subgrade and the character of traffic for

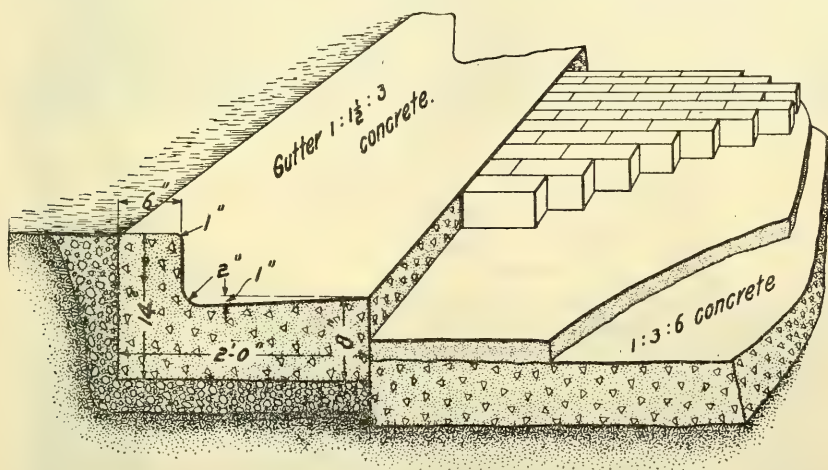


FIG. 2.—Concrete curb and gutter combined.

OPRE 8994

which the road is designed. Where the traffic is comparatively light and the subgrade is composed of some firm material which does not readily absorb water, a very satisfactory base may be constructed of broken stone. Where the traffic is comparatively heavy or where the material composing the subgrade is at all unstable, a monolithic concrete base should be used. Bases consisting of a course of brick laid flat upon a previously compacted layer of gravel or broken stone have sometimes been used, and pavements constructed upon bases of this kind, ordinarily called "double-layer" pavements, have in general proved satisfactory. At the present time, however, such bases can rarely be constructed at less cost than the more durable concrete bases, and they will therefore be given no further consideration here.

Broken-stone bases should be from 6 to 8 inches thick after compacting and should be constructed in two or more courses just as in

the case of first-class macadam roads. The stone should be durable, and should be graded in size between certain reasonable, fixed limits. It should be uniformly spread on the road, either from dumping boards by means of shovels or from wagons especially designed to spread the material as it is being dumped. Where whole loads are dumped in one place and then spread out to the required depth, it is very difficult to obtain uniform density. Usually those spots where the loads are dumped are more densely compacted than the rest of the base, and this lack of uniformity very soon manifests itself by producing unevenness in the surface of the pavement. The broken stone should be compacted in the usual manner by rolling with a

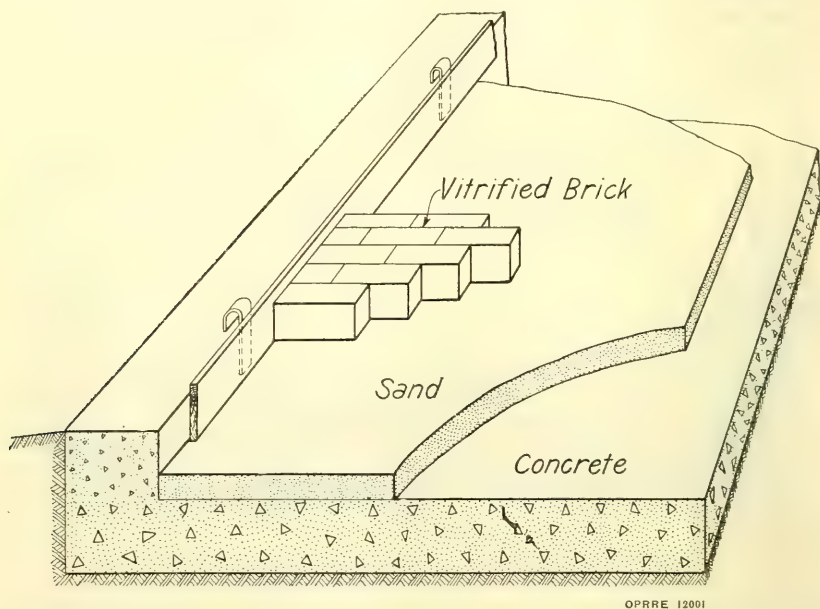
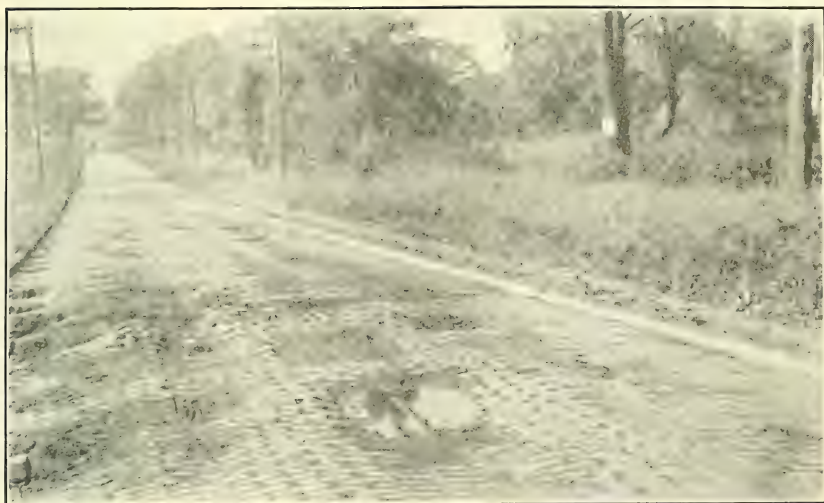


FIG. 3.—Making provision for expansion cushion.

power roller weighing not less than about 10 tons, and sufficient stone screenings and coarse sand to fill the voids should be spread and flushed into the base while the rolling is in progress. When complete the base should present a surface uniform in grade and cross section and parallel to the proposed surface of the finished pavement.

Concrete bases are unquestionably better adapted for brick pavements than any other type. They are practically monolithic in form, nearly impervious to water, and possess a relatively high crushing strength. All of these qualities may be obtained with a relatively "lean" concrete if the subgrade has been properly prepared. Under ordinary circumstances a satisfactory base may be constructed of



OPRRE 12409

FIG. 1.—FAILURE OF BRICK ROAD NEAR ZANESVILLE, OHIO, DUE TO DEFECTIVE GRAVEL FOUNDATION AND 11-TON MOTOR-TRUCK TRAFFIC.



OPRRE 13006

FIG. 2.—FAILURE OF BRICK ROAD NEAR MANSFIELD, OHIO, DUE TO DEFECTIVE CONSTRUCTION AND HEAVY MOTOR-TRUCK TRAFFIC.



OPRE 13128

FIG. 1.—BRICK ROAD ON SAND FOUNDATION, HILLSBORO COUNTY, FLA.

Settlement along left curb might have been avoided by better preparation of the foundation and by use of Portland cement grout for filling the joints.



OPRE 13127

FIG. 2.—BRICK ROAD AT ORLANDO, FLA., SHOWING DISPLACEMENT OF MARGINAL BRICK DUE TO ABSENCE OF CURB.

concrete composed of 1 part of Portland cement, 3 parts of sand, and from 5 to 7 parts of broken stone or screened gravel.

The sand should be clean and well graded in size, and the stone or gravel should conform to the usual requirements for coarse aggregate to be used in concrete construction.

Brick pavements have in some cases been constructed with the subgrade as a foundation, and where the materials composing the subgrade possess considerable supporting power under all weather conditions to which the road is subjected, this method may prove fairly satisfactory. Perhaps the most notable examples of brick roads constructed in this way are to be found in the peninsular section of Florida, where the soil is composed essentially of sand and where there is no danger of upheaval due to frost action. At best, this method of construction could hardly prove satisfactory for any ordinary soil conditions above the thirty-fifth parallel of latitude, and even below that latitude it should necessarily be confined to localities where the soil is composed of sand, gravel, or some other material

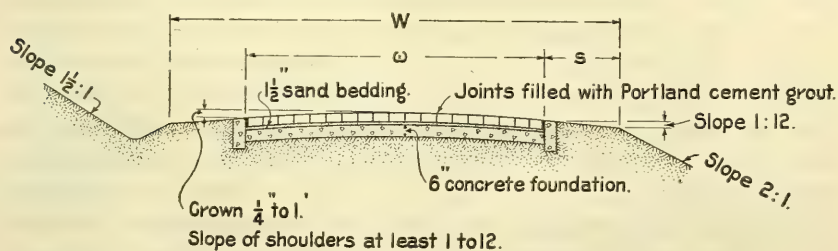


FIG. 4.—Typical section for a brick road.

which does not lose its stability when wet. Sand is the only material of this kind which is at all widely distributed. The precautions most necessary to observe in preparing sand foundations may be briefly described as follows:

(1) The road should be so graded and drained as absolutely to prevent the foundation from becoming saturated with either storm or ground water after the brick are laid.

(2) The entire roadway should be thoroughly saturated with water while it is being compacted, and a roller weighing not less than 10 tons should be used for compacting. Dry sand can not usually be compacted by rolling.

(3) Adequate stone or concrete curbs should always be provided. At present wooden boards are being used in lieu of curbs for many of the Florida roads, and in some cases this substitution can perhaps be justified by the immediate necessity for improving a large mileage of roads without suddenly increasing taxation to an unwarranted burden. On the other hand it seems very doubtful if any community

which can not afford proper construction in the beginning should select such an expensive type of surface for their roads.

(4) The material composing the foundation should be of a uniform character and free from vegetable matter of any kind. After the curbs are set, the foundation should be rerolled and reshaped until it is firm and unyielding and conforms to the required grade and cross-section. In order to accomplish this final shaping, the sand must be kept moist, and it is usually necessary to provide a pipe line along the work to supply water for sprinkling the foundation.

Plate II, figure 1, shows how a brick road on a sand foundation has settled under the action of traffic. This settling would probably not have occurred if the above precautions had all been observed at the time of construction, though the fact that sand, instead of Portland cement grout, was used for filling the joints was no doubt a contributing weakness.

BEDDING.

Since it is practically impossible to construct an absolutely smooth base, and since there is always a slight variation in the size of paving brick, owing to differences in the amount of shrinkage at the time of burning, it is necessary to provide an adjustable bedding of some kind between the base and the brick in order to secure an even surface and a uniform bearing for the brick. Until recently sand has been almost exclusively used for this purpose and has in general proved satisfactory. The objections which have been advanced against the sand bedding are, first, that it may become saturated with water, which upon freezing might damage the pavement; second, that a gradual movement of the sand may occur under the jarring action of traffic and in this way the surface of the pavement may eventually become distorted; and, third, that the use of some material for the bedding which would bond the brick to the base would enable the pavement to distribute concentrated loads over a greater area of the subgrade than where a sand cushion is used. It has also been claimed that the sand bedding, by separating the brick from the base, is responsible for much of the noise produced by traffic over brick pavements. In order to overcome these objections some engineers are now providing that the bedding shall be constructed of a dry mixture of sand and Portland cement instead of sand alone. This mixture, which is called "dry mortar," becomes wet when the brick are sprinkled just prior to grouting, and upon hardening forms a partial bond between the base and the brick. When such a bond is formed the bedding is not disturbed by the jarring action of traffic and is also partially impervious to water. The dry mortar bedding is at present employed only where the base is made of concrete, and its use has by no means become general, even with the concrete base.

The proper thickness for the bedding depends, of course, upon the extent of the inequalities in the brick and the foundation. In the past, 2 inches has been the most usual thickness, but as the accuracy secured in constructing the base has increased, and as the size of paving brick has become more nearly uniform, the necessary thickness for the bedding has naturally diminished. At present a thickness of $1\frac{1}{2}$ inches is considered conservative where the bedding consists of sand alone, but where dry mortar is employed the inequalities should be so reduced that a thickness of 1 inch will be sufficient, because it is cheaper to make the surface of the base uniform than to supply the additional dry mortar which would otherwise be required.

Sand bedding should consist of moderately clean sand and be free from pebbles. If dirt or vegetable matter is present, it will soon be leached out and cause unevenness to develop in the pavement, while pebbles prevent the brick from securing a uniform bearing and ultimately produce the same result. It is also important that the sand should be dry when spread, especially if it is fine, because a comparatively small amount of moisture increases the volume of fine sand considerably, and moisture when present is not, as a rule, uniformly distributed. Even if it were uniformly distributed at the start, some spots would dry out more rapidly than others while the spreading was under way, and a lack of uniformity would thus be produced in the bedding.

In forming the bedding the sand is uniformly spread over the base to a depth slightly in excess of that desired, and is then smoothed off by drawing over it a template shaped to conform with the cross section of the finished pavement. The length of the template is ordinarily made equal to the width of the pavement where this is less than about 25 feet, and equal to half the width for wider pavements. Timber guides may be laid in the same direction as the pavement for the template to slide on, or the curbs may be made to serve as guides where this is convenient.

After the bedding material is spread and uniformly "struck off" with the template to a depth slightly in excess of that required, it should be thoroughly compacted by rolling with a hand roller weighing from 300 to 400 pounds, and any depressions which form should be corrected. This is necessary in order to secure uniform density and to prevent unequal settlement of the surface.

If a dry mortar bedding is to be employed, the sand used should be clean and the manner of spreading and compacting the bedding should be practically the same as for sand alone. The proportion in which the sand and cement should be mixed is a subject regarding which there is more or less uncertainty at present. One part of

cement to five parts of sand is probably the most usual proportion. The mixing is generally done in a mechanical mixer, and the material is spread and compacted just in advance of the brick layers. It is of course essential that the bedding be kept dry until after the brick are laid.

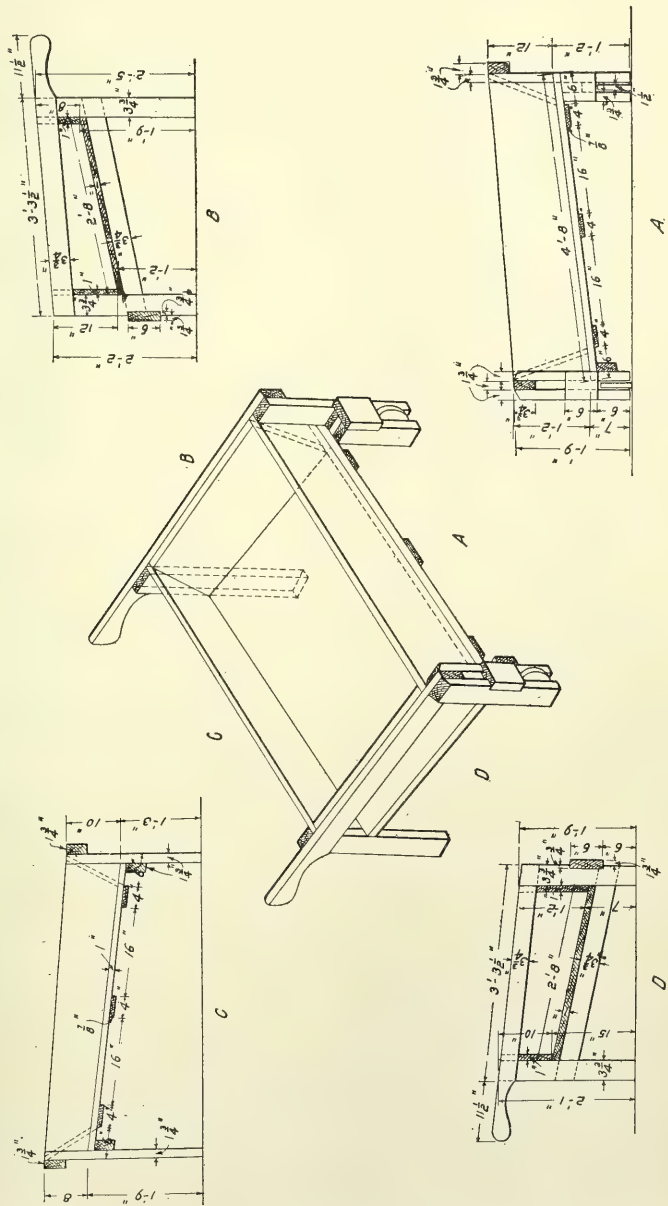
HANDLING AND LAYING THE BRICK.

The brick may all be hauled and piled at convenient intervals along the sides of the roadway before grading is begun, or, if more convenient, they may be delivered as needed on the work. Hauling over the finished pavement with wagons until it is complete and opened to traffic should be avoided. If the brick are delivered on the work as needed, they should be unloaded from the wagons outside of the curb and carried to the pavers, either by hand or in wheelbarrows. Plank trackways should also be provided over the newly laid pavement for the wheelbarrows when they are used.

The brick should in all cases be uniformly piled by hand on the new pavement conveniently close for the pavers, and each brick should be so placed that the regular operation of picking it up and placing it in the pavement will bring the best edge up. This method of handling the brick requires somewhat more labor than the common method of dumping them from wheelbarrows, but it eliminates to a great extent the practice of picking out and turning over chipped or kiln-marked brick after the pavement is laid. This is very objectionable on account of the disarrangement of the sand cushion, which is frequently occasioned.

The brick should be laid on edge and in uniform courses, running at right angles to the line of the pavement, except at intersections; and in order to "break the joints" each alternate course should begin with a half brick. In laying the brick the pavers stand on the pavement already laid and, being at the curb each time, carry across as many courses together as they can conveniently reach. The courses should be kept straight and close together, and, if necessary, each block of 8 or 10 courses may be driven back by means of a light sledge and a piece of straight timber approximately 2 by 4 inches by 5 or 6 feet long, though no heavy driving should be permitted. The brick should also be laid close together in the courses.

After the brick are laid the pavement should be carefully inspected, for the purpose of detecting soft or otherwise defective brick. Misshapen or broken brick may be detected by the eye alone, and the soft brick by sprinkling the pavement with water. The soft brick appear comparatively dry while the water is being applied and comparatively wet after the sprinkling is stopped. All defective brick should of course be replaced by others which meet the requirements of the specifications.





OPRRE 9791

FIG. 1.—FINE GRADING.



OPRRE 9790

FIG. 2.—ROLLING.

PREPARING THE SUBGRADE FOR A BRICK ROAD.

While there are a number of cases where brick have been laid flat and have made fairly satisfactory pavements for light traffic, there are probably very few cases where this practice has proved really economical in the long run.

TRUING THE SURFACE.

After the pavement has been laid and all defective brick have been replaced to the satisfaction of the engineer, the next step is to sweep the surface clean, and smooth out all inequalities by means of ramming and rolling. The rolling should be done with a power roller weighing from 3 to 5 tons, and the pavement should ordinarily be rolled in both longitudinal and diagonal directions. The longitudinal rolling should be done first, and should begin at the curbs and progress toward the crown. The roller should pass at least twice over every part of the pavement in each direction. In order to neutralize any tendency which the brick may have to careen under the roller, the number of forward trips over any part of the pavement should equal the number of trips backward over the same part.

In places where it is impracticable to use the roller for truing the surface—such, for example, as along the curbs or concrete gutters or around manholes—the brick should be brought to a true surface by means of ramming. For this purpose a wooden rammer loaded with lead and weighing from 80 to 100 pounds may be used. The blows of the rammer should not fall directly upon the brick, but should be transmitted through a 2-inch board laid parallel to the curb.

After the pavement has been trued up, as described above, it should be inspected again for broken or otherwise damaged brick, and also for those which have settled excessively, owing to some lack of uniformity in the bedding. All defects should be corrected, and the areas disturbed in making the corrections should be brought to a true surface by tamping or rolling. When the work of truing the surface is finished, the brick should be evenly bedded, but the amount of bedding material forced up into the joints should be inappreciable. If this is not the case, it is evidence that either the bedding has been poorly prepared or the rolling has been excessive.

FILLING THE JOINTS.

In order to keep the brick in proper position and protect the edges from chipping it is necessary to fill the joints with some suitable material before the road is opened to traffic. The materials which have in the past been most commonly used for this purpose are sand, various bituminous preparations, and a grout made of equal parts of Portland cement and fine sand mixed with water.

Sand is the least expensive of these materials, but there are several very serious objections to its use as a joint filler: (1) It does not protect the edges of the brick; (2) it is easily disturbed in cleaning the pavement and is likely to be washed out by rain on steep grades; (3) it does not entirely prevent water from penetrating through to the foundation; and (4) it does not bond the individual brick together and so enable them to present a concerted resistance to traffic.

The bituminous fillers vary considerably in quality and efficiency, but all are more or less unsatisfactory. One of the principal objections to their use is based on their tendency to run out of the joints into the gutters during warm weather and to crack and spall out during cold weather. This tendency can, of course, be partially overcome by exercising proper care in selecting the materials. It should also be noted in their favor that brick pavements, the joints of which have been filled with bituminous preparations, are ordinarily less noisy than those in which a Portland cement grout filler has been used. The grout filler is unquestionably very much superior from a standpoint of durability, however, and the excessive noise under traffic which has been frequently observed in connection with its use can be largely eliminated by the use of proper bituminous expansion cushions along the curbs. It is, therefore, recommended as better adapted for filling the joints in brick pavements than any other material which has been commonly used for that purpose.

When the joints of a brick pavement are properly filled with Portland cement grout the individual brick are firmly bonded together and, since the material composing the joints scarcely wears more rapidly than the brick, the edges of the brick are well protected.

When the pavement is constructed on a foundation other than concrete the advantages of using the grout filler are especially evident because of the protection thus afforded the foundation.

A satisfactory method for mixing and applying the grout filler by hand may be described as follows: Grout boxes, constructed in such manner that when resting on a level platform one corner will be lower than the others, should first be provided. A suitable design for such boxes is shown in Plate III. The number of boxes required depends on the width of the pavement; ordinarily one box to each 10 feet of width will be found sufficient. The grout, which should be put on in two applications, is prepared in batches each of which consist of a quantity of cement not exceeding one sack, a like amount of fine, clean sand, and water. The sand and cement should first be thoroughly mixed dry and sufficient water then added to produce a liquid mixture. The consistency of the mixture for the first application should be approximately the same as that of ordi-

nary cream and for the second application it should be somewhat thicker. Mechanical mixers have also been satisfactorily used for mixing and spreading the grout, and where the amount of work to be done is sufficient to warrant such an initial outlay, they are usually economical.

The pavement should be cleaned and thoroughly sprinkled as a preliminary to making the first application of grout, and it should be kept moist by gentle sprinkling while this application is being made. The grout should be swept into the joints immediately after it is removed from the boxes and spread upon the pavement. For this purpose a coarse rattan or fiber push broom should be used in the first application and a squeegee in the second application. The squeegee is usually made by clamping a piece of four-ply rubber belting or some other similar material, about 6 by 20 inches in size, between two pieces of board and attaching a suitable handle. The grout in the boxes should be continually stirred until the last of it is removed, otherwise a separation of the sand and cement will almost certainly occur.

The first application should proceed sufficiently far in advance of the second for the grout of the first application to settle, but not to take its initial set before the second application is made. Usually both applications are made by the same crew of laborers. They simply turn back after having covered the allowable distance with the first application and, mixing the grout in the same boxes, bring up the second application. The second application of grout should completely fill the joints flush with the top of the brick.

PROTECTING THE PAVEMENT.

After the joints are filled as described above and the grout has taken its initial set, the entire surface should be covered to a depth of approximately 1 inch with sand or fine earth. This is done to protect the pavement from the weather and to keep it in a moist condition while the grout is hardening. If necessary, in order to keep the covering moist, it should be occasionally sprinkled for several days after it is spread.

The covering should be permitted to remain on the surface for at least 10 days, and during this period the pavement should be kept entirely closed to traffic. If the weather is unfavorable, the length of time during which traffic is kept off the road should be increased.

EXPANSION CUSHIONS.

It has been customary in the past to provide both longitudinal and transverse bituminous expansion cushions in grout-filled brick pavements, but recent practice has demonstrated that the transverse

cushions may be advantageously omitted if proper longitudinal cushions are provided. The principal objection to the use of transverse expansion cushions is based on the fact that the material composing the cushions frequently softens during warm weather and runs out toward the curb, thus leaving the edges of the adjoining brick exposed to destructive impact from the wheels of passing vehicles. Even if the cushion consists of a material which does not run in warm weather, it is necessarily softer than the brick, and the natural result is still the development of unevenness in its immediate vicinity. No such objection can exist concerning longitudinal expansion cushions if they are placed adjacent to the curbs and constructed of proper material. They not only furnish a means for the pavement to expand and contract with changes in temperature, but they also eliminate to a large extent the disagreeable rumbling which has been so frequently associated with grout-filled brick pavements.

The bituminous material of which the expansion cushions are made should be such as to remain firm in summer and not to become brittle in winter. It should also possess the quality of durability. In order to insure that any given material is suited for such a purpose, it is usually considered necessary to prescribe certain laboratory requirements to which it must conform, and examples of these, which have been found to give good results, are contained in the section entitled "Typical specifications." (Cf. p. 26 et seq.)

Expansion cushions should be provided for at the time the brick are laid. This may be done by placing a board of the required thickness on edge adjacent to each curb, as shown in figure 3. Small iron wedges, such as are shown in this figure, may be inserted between the curb and the board at the time the board is set. These wedges may be readily loosened and removed after the brick have been laid and grouted, and may consequently be made to facilitate the removal of the board which provides space for the bituminous filler. If preferred, a bituminous felt board may be satisfactorily substituted for the poured cushion just described.

The proper thickness for expansion cushions is a matter concerning which much difference of opinion exists among highway engineers. Some engineers advocate a minimum thickness of 1 inch, while others claim to have secured their best results by using expansion cushions having a minimum thickness as low as three-eighths inch for very narrow pavements. It is generally agreed that the thickness of the cushion should vary with the width of the pavement. The following suggestions for proportioning the cushion are offered as being fairly representative of the best practice.



FIG. 1.—MIXING CONCRETE FOR THE BASE.



FIG. 2.—FINISHED CONCRETE BASE.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.



OPRRE 9231

FIG. 1.—SPREADING SAND CUSHION.



OPRRE 9225

FIG. 2.—ROLLING SAND CUSHION.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.



FIG. 1.—LAYING THE BRICK.

OPRRE 9227



FIG. 2.—ROLLING THE PAVEMENT.

OPRRE 9226

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.



OPRRE 9229

FIG. 1.—FILLING THE JOINTS, FIRST COAT.



OPRRE 9228

FIG. 2.—FILLING THE JOINTS, SECOND COAT.

EXPERIMENTAL ROAD AT CHEVY CHASE, MD.



FIG. 1.—FINISHED BRICK PAVEMENT PROTECTED BY SAND COVERING.

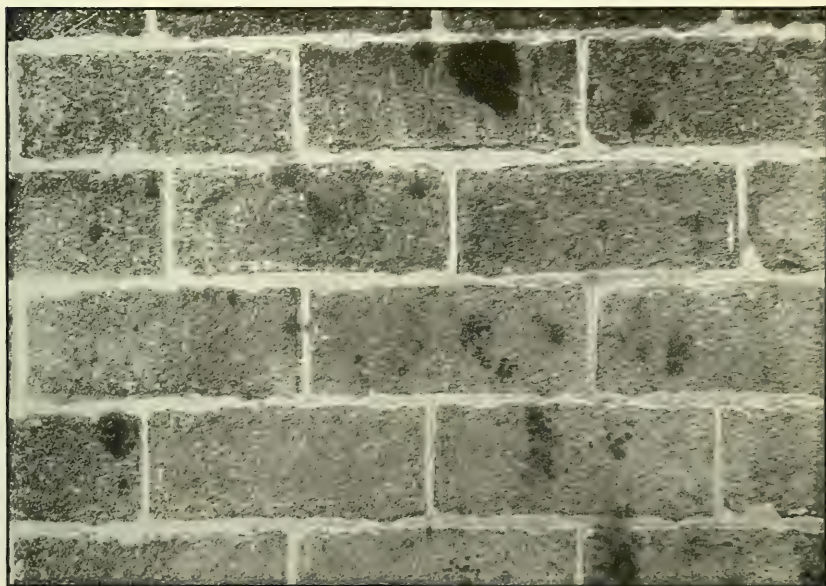


FIG. 2.—SHOWING PROPERLY FILLED GROUT JOINTS.
EXPERIMENTAL ROAD AT CHEVY CHASE, MD.



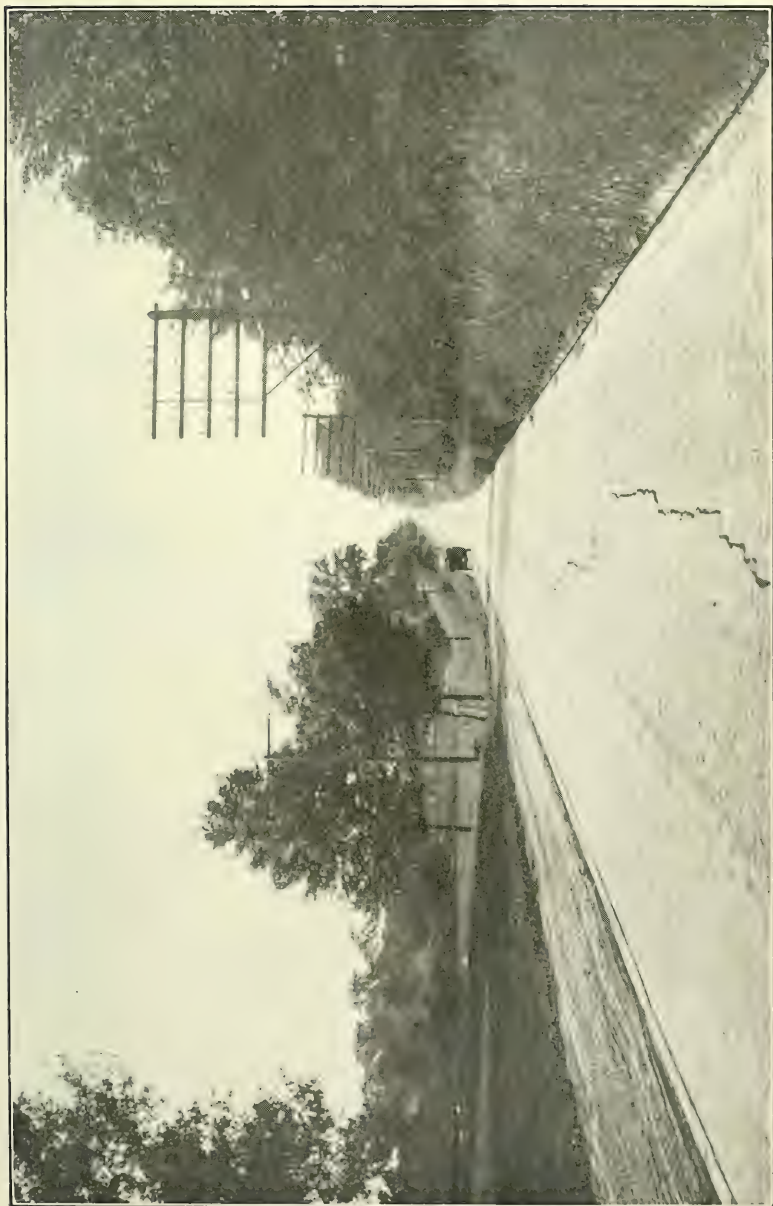
OPRRE 9937

FIG. 1.—EXPERIMENTAL ROAD AT CHEVY CHASE, MD.
Finished pavement in service.



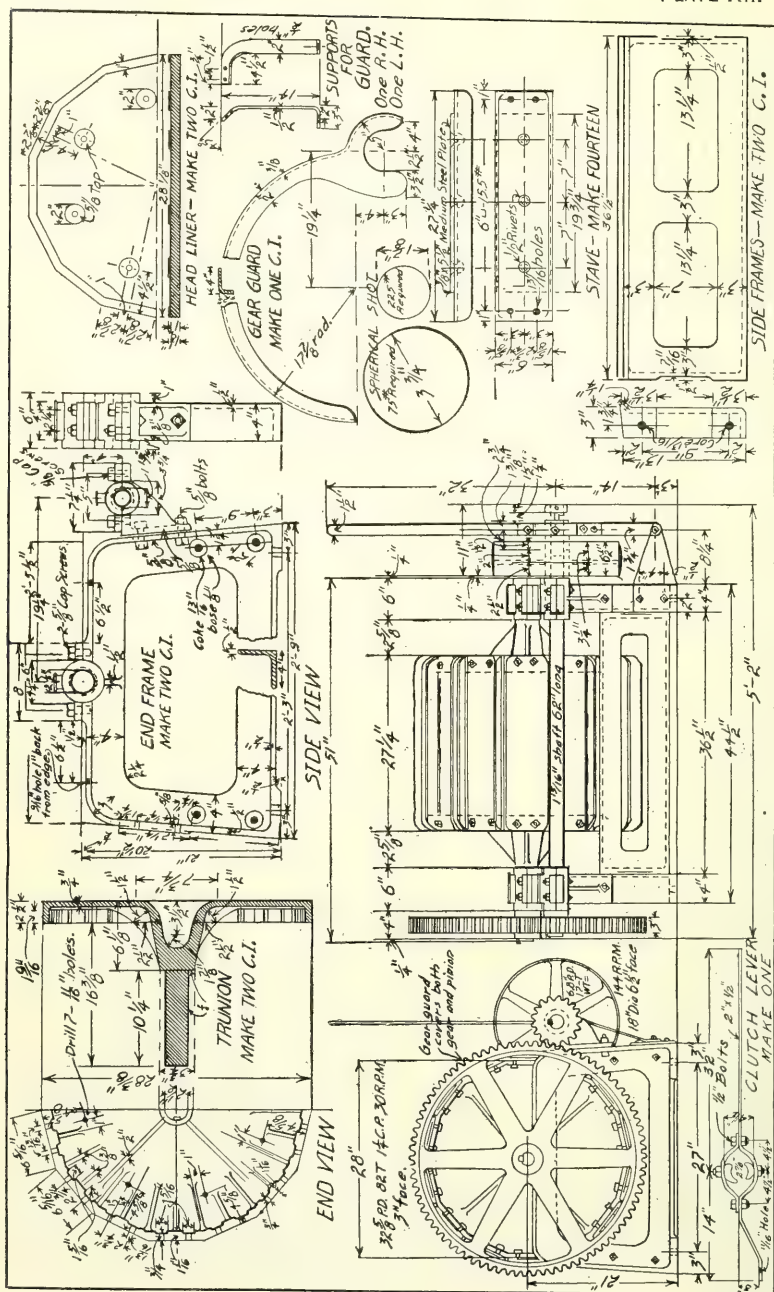
OPRRE 6044

FIG. 2.—GROUT-FILLED BRICK PAVEMENT, HAVING LONGITUDINAL JOINTS IN CENTER
AND OCCASIONAL TRANSVERSE JOINTS FILLED WITH SOFT FILLER.
Unightly appearance at right caused by widening roadway.



OPHRE 11134

GROUTED BRICK ROAD NEAR CLEVELAND, OHIO, SHOWING LONGITUDINAL CRACKS SUCH AS FREQUENTLY OCCUR IN BRICK PAVEMENTS, THE CAUSE OF WHICH CAN NOT ALWAYS BE DEFINITELY EXPLAINED.



PLAN FOR RATTLER.

TABLE 1.—*Ratio of thickness of cushions to width of roadway.*

Width of roadway (feet).	Thick- ness of cushion (inches).
20 or less.....	$\frac{1}{2}$
20 to 30.....	$\frac{3}{4}$
30 to 40.....	1
Over 40.....	$1\frac{1}{2}$

Plates IV to VIII, and Plate IX, figure 1, show the various steps in the construction of a brick pavement. Plate IX, figure 2, and Plate X, figure 1, show the finished pavement as it should appear, and Plate X, figure 2, shows the advantage possessed by grout-filled joints over joints filled with a soft material. The partial or total failures shown in Plates I, II, and XI are intended to emphasize the importance of employing proper methods, materials, and workmanship in brick-pavement construction.

“MONOLITHIC” BRICK PAVEMENTS.

During the year 1915 several sections of brick road were constructed in the vicinity of Paris, Ill., in accordance with an unusual method which offers at least partial promise of showing advantages not possessed by the common methods of construction now in use. The novel features of this work are: (1) The brick are laid upon a green concrete base with no intervening bedding other than a very thin layer of dry mortar spread by means of a specially designed templet; (2) no curbs are employed; (3) the construction of the base, the laying of the brick, and the grouting all proceed sufficiently close together to make the pavement practically a monolith, from which fact this type of brick pavement has been designated “monolithic.”

The advantages which the new type of brick pavement appears to possess may be briefly enumerated as follows:

(1) Economy in cost of construction. In addition to the saving in materials and labor effected by omitting the curbs, sand bedding, and expansion joints the labor cost can probably be somewhat further reduced by having the construction of the concrete base and the laying of the brick carried on under the same organization. The reduction in the time during which it is necessary to keep the highway closed to traffic, while the improvement is being made, is also an indirect economy.

(2) The elimination of the sand bedding would appear to be of advantage from a construction standpoint, because it is liable to be disturbed and to cause trouble in case of a heavy rain during construction. Sometimes, even after the pavement is completed, the sand is disturbed by water getting in between the brick and the base

through poorly grouted joints, or otherwise. Also, when a sand bedding is used, the joints between the brick are nearly always partially filled by sand being pushed up into them when the brick are rolled, and the effectiveness of the grout may be thereby greatly reduced.

(3) If the pavement continues to act as a monolith, the pressure on the subgrade, due to concentrated loads on the surface, will be much better distributed for the same depth of brick and base than if the two were separated and able to act independently.

The two principal objections to this type which suggest themselves at present are:

(1) The difference in the coefficients of expansion of brick and concrete may eventually cause a separation of the two materials, and as there is no adjustable bedding between them, any relative movement might result in shattering the bond between the brick and the grout. The only warrant for this apprehension at present, however, is in theory and not in fact.

(2) Whenever it becomes necessary to renew or repair the surface of the pavement, it will probably be necessary to renew the base also.

Until sufficient time has elapsed to show how this new type of pavement will be affected by changing temperatures and increasing age, no specific recommendations can be made concerning its adoption. But the indications are certainly sufficiently promising to warrant a careful watch being kept on these pavements and to encourage the undertaking of further experiments.

COST OF BRICK PAVEMENTS.

The cost of brick pavements varies widely and is affected by so many influences that it is difficult to attempt to derive a general expression showing the relation between probable cost and local conditions. The prices of brick, as also the prices of the various materials entering into the foundation, vary greatly according to the locality and the freight rate. The cost and efficiency of labor is also far from being constant. Furthermore, the material composing the subgrade and the method of preparing it may exert a marked influence on the cost of the pavement. The following statements regarding cost, then, must be considered as representing average conditions, and care must be exercised in applying them to special cases. They are intended as a guide in preparing estimates of probable cost.

The grading is usually paid for by the cubic yard, and the cost, of course, varies with the character of the soil and the necessary amount of excavation. In light, easily loosened soils, grading may usually be done at from 25 to 40 cents per cubic yard. In hard earth con-

taining more or less loose rock the cost per cubic yard generally runs from 40 to 75 cents, while grading in solid rock may sometimes cost as much as \$1.50 per cubic yard. The cost of the rough grading should be considered entirely apart from the cost of the pavement.

The cost of shaping and rolling the subgrade after the rough grading is completed will ordinarily vary from 3 to 5 cents per square yard. This cost should be included with the other items which make up the cost of the pavement.

The cost of the curbs varies with the character of the material used. Stone curbs ordinarily cost from 25 to 75 cents per linear foot, while curbs made of Portland cement concrete cost, as a rule, from 20 to 50 cents per linear foot. The higher prices for the concrete curbs apply principally to special cases requiring extra form work or considerable extra material.

The cost of the foundation depends largely on the cost of the materials with which it is constructed. Gravel or broken stone can usually be spread and rolled at from 5 to 7 cents per square yard, while the cost of these materials, delivered, varies from \$0.60 to \$2 per cubic yard. Mixing and placing concrete usually costs from 35 to 75 cents per cubic yard, according to the amount of work to be done and the methods employed, and the cost of the materials, delivered, ordinarily varies from \$2.50 to \$4.50 per cubic yard of concrete.

The cost of paving brick at the kiln varies from about \$13 to \$16 per thousand. Estimating 40 brick to the square yard, each 1,000 brick cover approximately 25 square yards, which makes the cost at the kiln per square yard of pavement vary from 55 cents to about 65 cents. These figures mean very little, unless the kiln is located conveniently near where the brick are to be used, for freight charges not infrequently amount to more than the cost of the brick.

The amount of joint filler required varies of course with the thickness of the joints. If grout is used as a filler, it is customary to estimate about 1 barrel of cement to each 25 square yards of pavement. If a bituminous filler is used, not more than about 1 gallon of bitumen should be required for each square yard of pavement.

A force consisting of one paver and five laborers should place on an average about 220 square yards of brick per 10-hour day; while supervision, rolling, and incidental expenses are ordinarily equivalent to the cost of hiring about three and one-half additional laborers.

If C = cost of cement per barrel, S = cost of sand per cubic yard, A = cost of coarse aggregate per cubic yard, B = cost of paving bricks per 1,000, and L = cost of labor per hour, with all materials considered delivered on the work and all costs expressed in cents, then the probable cost of constructing a brick pavement, including the

subgrade, a 6-inch concrete foundation, and suitable curbs, may be estimated by substituting in the formula:

$$\text{Cost per square yard} = 1.90 L + .213 C + .138 S + .157 A + .040 B.$$

The cost as estimated from this formula should usually be increased by about 10 per cent to allow for wear on tools and machinery and to guard against unforeseen contingencies. If it is desired to use a different thickness of foundation, it is safe to assume that each inch subtracted or added to the thickness of the foundation will make a corresponding difference of from 8 to 12 cents in the cost per square yard.

MAINTENANCE OF BRICK PAVEMENTS.

If brick pavements are properly constructed at the start, the work of maintaining them is very slight. Under the closest inspection, however, some inferior material is likely to become incorporated either in the foundation or in the surface, and it is therefore very important that a brick pavement be very carefully watched for the first few years of its life to see that no unevenness develops either because of defective brick having been used in the surface or because of insufficient support from the foundation at any point. Whenever any unevenness develops, it should be immediately rectified. Otherwise the pavement will become irregularly worn in the vicinity of the defects, and expensive repairs will eventually be necessary.

Not infrequently weak spots develop in broken stone or gravel foundations, owing to surface water finding its way through joints in the pavement which have not been properly filled with grout. Careful observation of the joints should therefore constitute a part of the early maintenance work, and any defective joints discovered should be immediately remedied. Where the foundation is constructed of concrete, however, slight defects in the joints seldom result in any very serious damage.

If care is exercised to correct all defects which appear within the first few years of the life of a well-constructed brick pavement, the work of maintaining the pavement proper should thereafter, except for cleaning, be almost negligible for a considerable period. The shoulders and drainage structures, of course, need occasional attention, just as in the case of any other pavement, but if they are properly constructed at the start repairs will usually be very slight.

The life of a well-constructed brick pavement can not be estimated with any great degree of exactness, first, because the traffic conditions are constantly changing, and, second, because no brick pavement which has been constructed in accordance with the best modern practice has yet worn out. Such measurements as have been made

of the amounts of wear sustained by given pavements during comparatively long periods of years have not been sufficient to warrant any very definite conclusions as to the probable terms of service, though they indicate that good paving brick wear very slowly under ordinary traffic. It is evident that in order to secure the full benefit of this excellent resistance to wear the surface of the pavement must not be permitted to become uneven because of the failure of a brick here and there.

CONCLUSION.

Before concluding this discussion of brick pavements, it would seem desirable to emphasize the importance of proper engineering supervision. In the past many communities have expended large sums in efforts to improve their public highways without first having secured the services of some one competent to plan and direct the work. The results have usually been very unsatisfactory under such circumstances and have frequently served to discourage further effort. One of the mistakes most commonly observed consists in constructing some expensive type of pavement on a road where the location is faulty or the grades are impracticable. Not infrequently sharp angles in the alignment or abrupt changes in the grade, which might be easily and inexpensively remedied by an experienced engineer, are left to impede traffic throughout the life of a costly and perhaps durable pavement.

Even in constructing common earth roads it is doubtful economy to dispense with the services of a competent engineer, and if any considerable quantity of work is to be done, such services should certainly be secured. Since brick pavements are probably more expensive to construct than any other type of pavement at present used for country roads, it is all the more important that their construction should be carefully planned and well executed.

APPENDIX A.

Typical Specifications for Constructing Brick Roads.

SPECIFICATIONS¹ FOR GRADING AND SURFACING WITH BRICK THE ----- ROAD.

Location.—The work referred to in these specifications is to be done on the ----- road, beginning at ----- and extending in a ----- direction through ----- to -----, a distance of ----- miles.

Work to be done.—The contractor shall do all clearing and grubbing, make all excavations and embankments, do all shaping and surfacing, (construct all drainage structures and other appertaining structures),² move all obstructions in the line of the work, and, unless otherwise provided in these specifications, shall furnish all equipment, materials, and labor for the same. In short, the contractor shall construct said road in strict accordance with the plans and specifications and shall leave the work in a neat and finished condition.

PLANS AND DRAWINGS.

The plans, profiles, cross sections, and drawings on file in the office of ----- at ----- show the location, profile, details, and dimensions of the work which is to be done. The work shall be constructed according to the above-mentioned plans, profiles, cross sections, and drawings, which shall be recognized as a part of these specifications. Any variation therefrom which may be required by the exigencies of construction will in all cases be determined by the engineer. On all drawings, figured dimensions are to govern in cases of discrepancies between scale and figures.

GRADING.

Grading shall include the moving of all earth, stone, and any other material that may be encountered, all filling, borrowing, trimming, picking down, shaping, sloping, and all other work that may be necessary to bring the road and subgrade to the required grade, alignment, and cross section, the clearing out of waterways and old culverts, the excavation of all necessary drainage and outlet ditches, the grading of a proper connection with all intersecting highways, the grubbing up and clearing away of all trees, stumps, and boulders within the lines of the improvement, and the removal of any muck, soft clay, or spongy material which will not compact under the roller, so as to make a firm, unyielding subgrade.

All trees, stumps, and roots within the limit of the improvement shall be grubbed up so that no part of them shall be within six (6) inches of the surface of the ground or within eighteen (18) inches of the surface of the subgrade.

¹ These specifications are substantially those prepared in the fall of 1913 by the Office of Public Roads for a project of considerable magnitude.

² The clause in parentheses should be omitted if plans and specifications for drainage structures are not included.

Embankments shall be formed of good, sound earth and carried up full width. The earth shall be deposited in layers not more than one (1) foot in thickness, and each layer shall be rolled until thoroughly compacted with a roller weighing not less than ten (10) tons. All existing slopes and surfaces of embankments shall be plowed or scarified where additional fill is to be made, in order that the old and new material may bond together. When sufficient material is not available within the fence lines to complete the embankments, suitable borrow pits, from which the contractor must obtain the necessary material, will be designated by the engineer. If there is more material taken from the cuts than is required to construct the embankments as shown on the plans, the excess material shall be used in uniformly widening the embankments or shall be deposited where the engineer may direct. Where embankments are formed of stone the material shall be carefully placed, so that all large stones shall be well distributed and the interstices shall be completely filled with small stone, earth, sand, or gravel, so as to form a solid embankment.

During the work of grading, the sides of the road shall be kept lower than the center and the surface maintained in condition for adequate drainage.

The grading of any portion of the road shall be complete before any surfacing material is placed on that portion; and where the plans do not call for any substantial change in the grade of any existing section of the road the surface shall be completely scarified to a depth of three (3) inches or more before the subgrade is prepared.

SUBGRADE.

The subgrade, or that portion of the road upon which the base for the brick roadway is to be laid, shall consist of good, sound earth brought to the proper elevation, alignment, and cross section, and shall be rolled until firm and hard. The rolling shall be done with a roller of the macadam type, weighing not less than ten (10) tons and not more than fifteen (15) tons. Should earth be encountered which will not compact by rolling, so as to be firm and hard, it shall be removed and suitable material put in its place, and that portion of the subgrade shall be again rolled. When the rolling is completed the surface of the subgrade shall conform to the cross section shown on the plans, and shall have the proper elevation and alignment, and shall be so maintained until the concrete base is in place.

MATERIALS.

Cement.—The cement for use in this work shall meet the requirements of the United States Government specifications for Portland cement as published in Circular No. 33, United States Bureau of Standards, issued May 1, 1912.

All cement shall be held at least ten (10) days after sampling before it is used in any part of the work. If the cement satisfactorily passes all tests that may be made within that time, it may be used, and the twenty-eight (28) day test will not be insisted upon; but if it should fail to pass satisfactorily any test made within that time, then the cement shall not be used until it has satisfactorily passed all tests, including the twenty-eight (28) day test. All cement shall be delivered on the work in cloth or paper bags, containing ninety-four (94) pounds, net weight, and this amount of cement shall be considered as having a volume of one (1) cubic foot. In order to allow ample time for inspecting and testing, the cement shall be stored in a suitable weather-tight building, having the floor blocked or raised from the ground, and shall be so stored as to permit of easy access for inspection, and so that each carload shipment may be readily identified.

Sand.—The sand for use as fine aggregate in all concrete or dry mortar shall be composed of particles of hard, durable stone and not more than three (3) per cent, by weight, of clay or silt. No clay, however, will be permitted if it occurs as a coating on the sand grains. The grains shall be of such sizes that all will pass a one-fourth ($\frac{1}{4}$) inch mesh screen, that not more than twenty (20) per cent will pass a No. 50 sieve, and that not more than sixty (60) per cent nor less than twenty (20) per cent will be retained on a No. 20 sieve. The sand shall be of such quality that a mortar made in the proportion of one (1) part of cement to three (3) parts of the sand, according to standard methods, when tested at any age not exceeding twenty-eight (28) days, will have a tensile strength of at least one hundred (100) per cent of that developed in mortar of the same proportions made of the same cement and standard Ottawa sand. The cement used in these tests shall be from an accepted shipment of that proposed for use with the sand.

The sand for sand bedding shall be composed of particles of hard, durable stone and not more than five (5) per cent, by weight, of clay, loam, or silt. The sizes of the grains shall be such that all will pass a one-fourth ($\frac{1}{4}$) inch mesh screen and not more than fifty (50) per cent will pass a No. 30 sieve. Stone screenings will not be accepted for use in the sand bedding.

The sand for the grout filler shall be composed of quartz grains and not more than one (1) per cent, by weight, of clay or silt. The grains shall be of such size that all will pass a No. 20 sieve and that not more than forty (40) per cent will pass a No. 50 sieve. The sand shall be of such quality that a mortar made in the proportion of one (1) part of cement to three (3) parts of the sand, according to standard methods, when tested at any age not exceeding twenty-eight (28) days, will have a tensile strength of not less than seventy-five (75) per cent of that developed in mortar of the same proportions made of the same cement and standard Ottawa sand. The cement used in these tests shall be from an accepted shipment of that proposed for use with the sand.

Gravel.—The gravel for use in the concrete base shall be composed of hard, sound, durable particles of stone and not more than three (3) per cent, by weight, of clay or silt. No clay, however, will be permitted if it occurs as a coating on the particles of stone or as lumps more than one (1) inch in diameter. The particles of stone shall be graded in size between those retained on a screen having circular openings one-fourth ($\frac{1}{4}$) inch in diameter, or a one-fourth ($\frac{1}{4}$) inch mesh screen, and those passing a screen having circular openings two (2) inches in diameter. Not more than seventy-five (75) per cent of the particles shall pass and not more than seventy-five (75) per cent shall be retained on a screen having circular openings three-fourths ($\frac{3}{4}$) inch in diameter.

The gravel for use in the concrete curbs shall be composed of hard, sound, durable particles of stone, thoroughly clean and graded in size between those retained on a screen having circular openings one-fourth ($\frac{1}{4}$) inch in diameter, or a one-fourth ($\frac{1}{4}$) inch mesh screen, and those passing a screen having circular openings one (1) inch in diameter. Not less than forty (40) per cent shall be retained on and not less than twenty (20) per cent shall pass a one-half ($\frac{1}{2}$) inch mesh screen.

Crushed stone.—The crushed stone for use in the concrete base shall be clean, sound, and durable, and shall be composed of all that part of the product of the crusher which is retained on a screen having circular openings one-fourth ($\frac{1}{4}$) inch in diameter, or a one-fourth ($\frac{1}{4}$) inch mesh screen, and which passes a screen having circular openings two (2) inches in diameter. A sample of the stone, when subjected to the physical tests as described in the United States

Department of Agriculture Bulletin No. 347, shall satisfactorily meet the following requirements:

Hardness not less than ten (10), toughness not less than five (5), and per cent of wear not more than twelve (12).¹

The crushed stone for use in the concrete curb shall be clean, sound, and durable, and shall be composed of all that part of the product of the crusher which is retained on a screen having circular openings one-fourth ($\frac{1}{4}$) inch in diameter, or a one-fourth ($\frac{1}{4}$) inch mesh screen, and which passes a screen having circular openings one and one-fourth ($1\frac{1}{4}$) inches in diameter. A sample of the stone, when subjected to the physical tests as described in the United States Department of Agriculture Bulletin No. 347, shall satisfactorily meet the following requirements:

Hardness not less than twelve (12), toughness not less than six (6), and per cent of wear not more than ten (10).¹

Slag.—The slag for use in the concrete base shall be steel-furnace slag, broken to such sizes that all of the particles will pass a screen having circular openings two (2) inches in diameter and will be retained on a screen having circular openings one-fourth ($\frac{1}{4}$) inch in diameter, or a one-fourth ($\frac{1}{4}$) inch mesh screen. Not more than seventy-five (75) per cent of the particles shall pass and not more than seventy-five (75) per cent shall be retained on a screen having circular openings three-fourths ($\frac{3}{4}$) inch in diameter.

The material shall be reasonably uniform in character, and a sample, when subjected to the physical tests, as described in United States Department of Agriculture Bulletin No. 347, shall satisfactorily meet the following requirements:

Specific gravity not less than two and one-tenth (2.1), hardness not less than fifteen (15), toughness not less than five (5), and per cent of wear not more than fifteen (15).

Water.—The water used in the mixing of concrete or grout shall be free from oil, acid, alkali, or vegetable matter, and fairly free from clay or silt.

Brick.—The brick shall be standard wire-cut lug or re-pressed paving block. The standard size of brick shall be three and one-half ($3\frac{1}{2}$) inches in width, four (4) inches in depth, and eight and one-half ($8\frac{1}{2}$) inches in length. The brick shall not vary from these dimensions more than one-eighth ($\frac{1}{8}$) inch in width and depth and not more than one-half ($\frac{1}{2}$) inch in length, and in brick of the same shipment the maximum width or depth shall not vary from the minimum width or depth more than one-eighth ($\frac{1}{8}$) inch. All brick must be thoroughly annealed, regular in size and shape, and evenly burned. When broken they shall show a dense, stonelike body, free from lime, air pockets, cracks, and pronounced laminations. No surface of any brick shall have kiln marks more than three-sixteenths ($\frac{3}{16}$) inch in depth or cracks more than three-eighths ($\frac{3}{8}$) inch in depth, and the wearing surface of the brick shall not have kiln marks more than one-sixteenth ($\frac{1}{16}$) inch in depth and shall be free from cracks. The brick shall have not less than four (4) and not more than six (6) lugs, all on one side of the brick, such that when the brick are properly laid in place in the pavement the joints between them will be not less than one-eighth ($\frac{1}{8}$) nor more than one-fourth ($\frac{1}{4}$) inch in width. The name or trade-mark of the manufacturer, if shown on the brick, must be recessed and not raised. If the edges of the brick are rounded, the radius shall not exceed one-eighth ($\frac{1}{8}$) inch.

The brick must not be chipped in such a manner that the wearing surface is not intact or that the lower or bearing surface is reduced in area more

¹ The values given for hardness, toughness, and per cent of wear are intended to exclude unsatisfactory stone, but in communities where better stone is readily available the requirements should be made more rigid.

than ten (10) per cent; but chipped brick, if otherwise satisfactory, may be used in obtaining the half brick for breaking courses and the necessary pieces of brick for closures. The brick shall not be salt glazed or otherwise artificially glazed. Not less than five (5) samples of ten (10) brick each will be selected from each kiln or shipment and subjected to the rattler test recommended to the American Society for Testing Materials by its subcommittee on paving brick; one sample from what appears to be the softest brick, which shall not lose of its weight more than twenty-four (24) per cent; one sample from what appears to be the hardest brick, which shall not lose of its weight less than sixteen (16) per cent or more than twenty-four (24) per cent; and three samples representing an average of the kiln or shipment, which shall not lose of their weight more than twenty-two (22) per cent: *Provided, however*, That if the softest brick lose less than twenty-four (24) per cent, the permissible minimum loss of the hardest brick will be reduced a like amount. If the kiln or shipment of brick should fail to meet the above requirements—and it is fair to assume that it would meet them if not more than ten (10) per cent were culled—then the contractor may, at his option, regrade the brick. When the regrading is complete the kiln or shipment will be resampled and retested as under the original conditions, and if it fails to meet any of the above requirements it will be finally and definitely rejected. Sampling will be done at the factory prior to shipment or from cars when placed on siding at destination, and brick satisfactorily passing the rattler test will not be rejected as a whole, but will be subject to such culling as may be necessary to meet all of the above requirements. The brick shall be carefully unloaded from cars and wagons by hand and neatly piled along the work in such manner that they will be clean and in proper condition to be laid in the pavement when desired.

Bituminous filler for expansion cushion.—The bituminous filler for the expansion cushion between the brick pavement and the curb shall be a blown-oil asphalt. It shall be soluble in chemically pure carbon disulphide to at least ninety-nine (99) per cent, and when tested by the cube method, as described in United States Department of Agriculture Bulletin No. 314, its melting point shall not be less than ninety (90) degrees centigrade and not more than one hundred and ten (110) degrees centigrade. The penetration at zero (0) degrees centigrade of a No. 2 needle acting one (1) minute under a weight of two hundred (200) grams shall be not less than two (2) millimeters. The penetration at forty-six (46) degrees centigrade of a No. 2 needle acting five (5) seconds under a weight of fifty (50) grams shall not exceed ten (10) millimeters.

CONSTRUCTION.

Concrete base.—Upon the subgrade prepared as herein specified shall be laid a concrete base of the width and thickness shown on the plans. The subgrade shall be wet but not muddy when the concrete is placed upon it. The concrete shall be composed of the following materials, by volume: One (1) part of cement, three (3) parts of sand, and five (5) parts of gravel, crushed stone, or crushed slag, and sufficient water to form a quaky mass, and shall be thoroughly mixed in a machine mixer of the batch type so constructed and operated that the thorough mixing of the materials will be assured. The concrete shall be so delivered to its place on the subgrade as not to cause or permit any separation of the materials. Wheelbarrows or other devices used for measuring the materials shall be of uniform capacity. The concrete shall be deposited in place immediately after it is mixed and shall be well compacted as fast as it is placed. The top surface shall be smoothed by troweling with

shovels or by some other means approved by the engineer, and when completed shall not vary more than one-half ($\frac{1}{2}$) inch from the proper shape and grade, as shown on the plans and profiles. The concrete base shall be kept wet by sprinkling with water during the first four (4) days after it is laid. No hauling over it or rolling or tamping of brick upon it will be permitted for seven (7) days after it is placed, and during this time it shall be properly protected from injury. Concrete shall not be mixed when the temperature of any of the materials is less than thirty-five (35) degrees Fahrenheit. Concrete shall not be used after it has begun to show evidence of setting, and no concrete which has once set shall be used as material for mixing a new batch.

Curbs.—Concrete curbs shall be built on the base as shown on the plans. The concrete shall be composed of the following materials, by volume: One (1) part of cement, one and one-half ($1\frac{1}{2}$) parts of sand, three (3) parts of gravel or crushed stone, and water. The materials shall be thoroughly mixed in a machine mixer of the batch type or by hand. If the mixing is done by hand, it shall be done upon a water-tight platform with raised edges, in such manner as to insure thorough mixing of the materials and to meet the approval of the engineer. The concrete for the curb shall be placed upon the base before the concrete of either the curb or the base has taken its initial set, and care shall be taken, such as roughening the concrete of the base and tamping the concrete of the curb, to insure that the curb will be firmly bonded to the base. The concrete shall be well tamped and spaded along the forms, so that when they are removed there will be no open and porous places on the sides of the curb. The top surface of the curb shall be floated or troweled to a smooth finish. The forms for the curb shall be smooth, clean, free from warp, and of sufficient strength to resist springing out of shape. They shall be well staked and braced, and the top edges shall be at the same height and set true to line. To protect the curb from drying out too rapidly it shall, within twelve (12) hours after it is placed, be covered with gunny cloth, which shall be kept wet for five (5) days.

*Sand bedding.*¹—Upon the base shall be spread a bedding of sand such that it will have a uniform depth of approximately one and one-half ($1\frac{1}{2}$) inches when compacted. The base shall be thoroughly clean at the time the bedding is spread. The bedding shall be carefully shaped to a true cross section of the roadway by means of a template having a steel-faced edge, and so fitted as to be readily drawn on the curb. After the bedding is so shaped, it shall be rolled with a hand roller until the material composing it is well compacted. The depressions formed by rolling shall be filled and the surface of the bedding trued up with the template and rolled again. This operation of filling depressions, truing up with template, and rolling shall be repeated as often as is necessary to secure a well-compacted bedding true to grade and to the required cross section. The rolling shall be done with a hand roller not less than twenty-four (24) inches in diameter, not less than twenty-four (24) inches in width, and weighing not less than ten (10) pounds per inch of width.

Laying brick.—Upon the bedding, prepared as above described, the brick shall be laid on edge from curb to curb in straight courses at right angles to the curb, with the lug sides all in the same direction. The brick shall be laid so that the lugs of the brick in one course will touch the brick in the adjoining

¹ If a dry-mortar bedding is to be used substitute the following:

Dry-mortar bedding.—Upon the base shall be spread a dry-mortar bedding composed of 1 part of Portland cement to 5 parts of sand thoroughly mixed. The dry mortar shall be spread in such quantity as to give an average depth of approximately 1 inch when compacted. The base shall be thoroughly clean at the time the bedding is spread, etc.

course, and the joints between the ends of the brick shall not exceed one-eighth ($\frac{1}{8}$) inch in width. Joints shall be broken by starting each alternate course with a half brick. Nothing but whole brick shall be used, excepting the half brick for starting alternate courses and pieces of brick for closures, and no piece of brick less than two (2) inches in length shall be used for making a closure. The cutting and trimming of brick shall be done by experienced men, and proper care shall be taken not to check or fracture the part to be used, and the ends of the part used shall be square with its top and sides.

The brick shall be carried to the bricklayers on pallets or in clamps and not wheeled in barrows. The bricklayers laying the brick shall stand on the brick already laid and shall not in any manner disturb the bedding. No heavy driving will be permitted to straighten courses, and in making closures the pieces of brick shall be so cut that they may be laid in place without driving. Brick shall be laid with the best edge up. Batting for closures shall progress with the laying.

After the brick are laid they will be carefully inspected, and all those which are soft, cracked, glazed, spalled, overburned, or otherwise imperfect will be marked by the inspector. The contractor shall at once remove such brick from the pavement with flat-nosed tongs, without disturbing the bedding, and shall replace them with approved brick. Kiln-marked and slightly chipped brick, if not otherwise defective, may be turned over and, if the reverse edge is smooth, may remain in the pavement.

If more than one kind of brick or the brick from more than one plant is furnished for the work, each particular kind or make shall be laid in a separate section.

Rolling brick.—After the brick have been laid and after all objectionable brick have been removed from the pavement they shall be brought to a true surface by means of rolling. The rolling shall be done with a motor or steam tandem roller weighing not less than three (3) and not more than five (5) tons. The pavement shall be rolled in longitudinal and diagonal directions. The longitudinal rolling shall begin at the curbs and progress toward the center of the pavement. The pavement shall then be thoroughly rolled diagonally at an angle of forty-five (45) degrees with the curb. When this rolling has been completed the brick will again be inspected, and all that are broken or damaged shall be removed from the pavement and replaced with approved brick. If necessary to secure a uniform surface the brick shall then be again rolled, the roller moving diagonally across the pavement at right angles to the first diagonal rolling. To prevent the brick from being left careened the roller shall in all cases cover exactly the same area in making its backward trip as was covered in its forward trip, and shall proceed at a very slow rate of speed until the entire pavement has received the first rolling. In no event shall the rolling be done when the bedding is in a condition such that the sand or dry mortar will flow up into the joints more than three-eighths ($\frac{3}{8}$) inch.

Filling the joints.—After the brick have been rolled as above specified the joints between them shall be filled with a grout containing equal parts of cement and sand. The grout shall be mixed in a mechanical batch mixer or by hand in batches containing not more than one sack of cement. Hand mixing shall be done in a box about five (5) feet long, thirty (30) inches wide, and fourteen (14) inches deep, resting on legs of different lengths, so that the mixture will readily flow to the lowest corner of the box. The sand and cement shall be thoroughly mixed dry. Sufficient clean water shall then be admixed to produce a grout of a consistency about equal to that of ordinary cream for the first application and of a slightly thicker consistency for subsequent applications. From the time the water is added to the mixture until all of the

grout is removed from the box, the mixture must be constantly well stirred with mortar hoes. The grout shall be removed from the box with scoop shovels and applied to the brick in front of men supplied with push brooms, who shall rapidly sweep it lengthwise of the brick into the joints until the joints are practically-filled. After the first application has been made and the grout has settled into the joints, and before initial set has taken place, the unfilled portion of the joints shall be filled with the thicker grout, and, if necessary, refilled until the joints remain full to the top. After this has been done the pavement shall be finished to a smooth surface, free from any surplus grout, with a squeegee, which shall be worked over the brick at an angle of about forty-five (45) degrees with the curb. The pavement shall have been thoroughly sprinkled before the first application of grout is made, and shall be kept moist by means of gentle sprinkling until the grout is spread. The top surface, sides, and ends of the brick shall be thoroughly clean at the time the work of filling the joints is done.

Immediately after the grout has taken its initial set the pavement shall be covered with a one (1) inch layer of sand or earth. This layer, immediately after it is placed on the pavement, shall be thoroughly wet by sprinkling and shall be kept wet by sprinkling for at least the five (5) following days. It shall remain on the pavement for at least ten (10) days and shall be removed before traffic is permitted upon the pavement. During this period of ten (10) days or longer, as the engineer may require on account of weather conditions, no traffic shall be allowed upon and no materials shall be placed upon the pavement.

*Expansion cushion.*¹—An expansion cushion four (4) inches in depth and of the thickness indicated on the plans shall be constructed along each curb as follows: Suitable provision for the cushion shall be made at the time the brick are laid by setting boards of the proper width and thickness on edge in proper position along the curb. After the brick have been laid, rolled, and grouted, and the grout has well set, the boards shall be carefully removed, so as not to damage the curb or the brick pavement, and the spaces which they occupied shall be filled with blown-oil asphalt heated to a temperature of not less than three hundred (300) degrees Fahrenheit and not more than four hundred (400) degrees Fahrenheit.

ALTERNATE SPECIFICATIONS.

SEPARATE CONCRETE CURBS.

Where the plans call for concrete curbs separate from the foundation they shall be constructed before the subgrade is finally completed and shall have the cross section shown on the plans. Such curbs shall be constructed in sections not less than six (6) feet and not more than twelve (12) feet in length and shall be true to grade and alignment.

The specification already given for concrete curbs constructed in combination with the foundation shall also apply to curbs constructed separate from the foundation as regards proportioning, mixing, and placing the concrete, constructing the forms, and all other features of construction which are not covered on the plans or in this specification.

STONE CURBS.

Where stone curbs are required, they shall be hauled and set before the subgrade is finally completed. The curbs shall be set true to line and grade

¹ Instead of making a poured joint, as above described, the cushion may be constructed of some of the specially prepared expansion-joint materials, subject to the approval of the engineer as to the material and method of construction.

and shall be securely bedded in broken stone, gravel, or firm earth. In preparing the trenches for the curbs great care shall be exercised to see that the material upon which the curb is to be set is well compacted, firm, and hard.

Stone curbing shall be quarried from hard, tough, homogeneous stone. The individual blocks shall have the cross section shown on the plans and shall be not less than four (4) feet in length. Each block shall be free from seams and all other imperfections and shall be neatly dressed and finished on all exposed faces.

APPENDIX B.

Method for Inspecting and Testing Paving Brick.¹

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side, shall be determined by the following procedure, viz:

(1) *The rattler test*, for the purpose of determining whether the material as a whole possesses to a sufficient degree, strength, toughness, and hardness;

(2) *Visual inspection*, for the purpose of determining whether the physical properties of the material as to dimensions, accuracy and uniformity of shape and color are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

SECTION 1.—THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TEST.

ITEM 1. *Place of sampling*.—In general where a shipment of brick involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, or on cars at their destination, or on the street when delivered ready for use. When the quantity under consideration exceeds 100,000, the sampling shall be done at the factory prior to shipment. Brick accepted as the result of tests prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Section II (Visual Inspection).

ITEM 2. *Method of selecting samples*.—In general the buyer shall select his own samples from the material which the seller promises to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include brick which would be rejected by visual inspection as provided in Section II, except that where controversy arises, whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller, and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

ITEM 3. *Number of samples per lot*.—In general one sample of 10 brick shall be tested for every 10,000 brick contained in the lot under consideration,

¹ Recommended by subcommittee on paving brick of the American Society for Testing Materials.

but where the total quantity exceeds 100,000, the number of samples tested may be fewer than 1 per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot.

ITEM 4. *Shipment of samples.*—Samples which must be transported long distances by freight or express must be carefully put up in packages holding not more than 12 brick each. When more than six brick are shipped in one package, it must be so arranged as to carry two parallel rows of brick side by side, and these rows must be separated by a partition. In event of some of the brick being cracked or broken in transit, the sample shall be disqualified if there are not remaining 10 sound undamaged brick.

ITEM 5. *Storage and care of samples.*—Samples must be carefully handled to avoid breakage or injury. They must be kept dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° F. before testing.

THE CONSTRUCTION OF THE RATTLER.

ITEM 6. The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of materials and dimensions, and shall consist of barrel, frame, and driving mechanism as herein described. Accompanying these specifications is a complete drawing (Pl. XII) of a rattler which will meet the requirements, and to which reference should be made.

ITEM 7. *The barrel.*—The barrel of the machine shall be made up of the heads and head liners and staves and stave liners.

The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ inches in diameter and shall have a bearing 6 inches in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{8}$ -inch shafts, and shall be keyseated for two keys, each $\frac{1}{2}$ inch by $\frac{3}{8}$ inch and spaced 90° apart. The shaft shall be a snug fit, and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ inches in the head for the driving end of the rattler and $11\frac{3}{8}$ inches long for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ inches.

The heads shall be not less than $\frac{3}{8}$ inch nor more than $\frac{7}{8}$ inch thick. In outline each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ inches in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ inch thick and extending outward $2\frac{1}{2}$ inches from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head must be smooth and must give a true and uniform bearing for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head must be either ground or machined. The flanges shall be slotted on the outer edge so as to provide for two $\frac{3}{4}$ -inch bolts at each end of each stave, said slots to be $1\frac{1}{8}$ inch wide and $2\frac{3}{8}$ inches center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ inch thick extending down the outward side of the head not less than 2 inches.

There shall be for each head a cast-iron head liner $1\frac{1}{2}$ inch in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{3}{8}$ inches in diameter. This head liner shall be fastened to the head by seven $\frac{5}{8}$ -inch cap screws through the head from the outside. Whenever these head liners become worn down $\frac{1}{2}$ inch below their initial surface level at any point of their surface they must be replaced with new ones. The metal of these head liners shall be

hard machinery iron and should contain not less than 1 per cent of combined carbon.

The staves shall be made of 6-inch medium steel structural channels 27½ inches long and weighing 15.5 pounds per linear foot. The staves shall have two holes 1½ inch in diameter, drilled in each end, the center line of the holes being 1 inch from the end and 1½ inches either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but must not exceed ⅝ inch.

The interior or flat side of each stave shall be protected by a liner ¾ inch thick by 5½ inches wide by 19½ inches long. The liner shall consist of medium steel plate and shall be riveted to the channel by three ½-inch rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 inches from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once riveted.

Any test at the expiration of which a stave liner is found detached from the stave or seriously out of position shall be rejected. When a new rattler in which a complete set of new staves is furnished is first put into operation, it shall be charged with 400 pounds of shot of the same sizes, and in the same proportions as provided in Item 9, and shall then be run for 18,000 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time, in such a way that of each pair one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive, but not contiguous; for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative condition of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of newly lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 inches long, inside measurement, between head liners. The liners of the staves must be so placed as to drop between the head liners. The staves shall be bolted tightly to the heads by four ¾-inch bolts, and each bolt shall be provided with a lock nut, and shall be inspected at not less frequent intervals than every fifth test, and all nuts shall be kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

ITEM. 8. *The frame and driving mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The countershaft upon which the driving pinion is mounted shall not be less than 1½ inches in diameter, with bearings not less than 6 inches in length. If a belt drive is used, the pulley shall not be less than 18 inches in diameter and 6½ inches in face. A belt at least 6 inches in width, properly adjusted to avoid unnecessary slipping, should be used.

ITEM 9. *The abrasive charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 inches in diameter and shall weigh approximately 7.5 pounds (3.40 kilos) each. Ten spheres of this size shall be used.

These shall be weighed separately after each 10 tests, and if the weight of any large sphere falls to 7 pounds (3.175 kilos), it shall be discarded and a new one substituted, provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller sized spheres shall be 1.875 inches in diameter and shall weigh approximately 0.95 pound (0.43 kilo) each. In general the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly as possible 300 pounds. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 inches in diameter, drilled in an iron plate $\frac{1}{4}$ inch in thickness, or weigh less than 0.75 pound (0.34 kilo). Further, the small spheres shall be tested by passing them over the above plate, or shall be weighed after every 10 tests, and any which pass through the plate or fall below the specified weight shall be replaced by new spheres; and provided further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon, not less than 2.50 per cent.

Graphitic carbon, not more than 0.25 per cent.

Silicon, not more than 1 per cent.

Manganese, not more than 0.50 per cent.

Phosphorus, not more than 0.25 per cent.

Sulphur, not more than 0.08 per cent.

For each new batch of spheres used the chemical analysis must be furnished by the maker or be obtained by the user before introducing into the charge, and unless the analysis meets the above specifications the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

ITEM 10. *The brick charge.*—The number of brick per test shall be 10 for all bricks of so-called "block size," whose dimensions fall between from 8 to 9 inches in length, 3 to $3\frac{1}{4}$ inches in breadth, and $3\frac{3}{4}$ inches to $4\frac{1}{4}$ inches in thickness.¹ No brick should be selected as a part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

ITEM 11. *Speed and duration of revolution.*—The rattler shall be rotated at a uniform rate of not less than $29\frac{1}{2}$ nor more than $30\frac{1}{2}$ revolutions per minute, and 1,800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin of not to exceed 10 revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If from accidental causes the rattler is stopped and started more than once during a test and the loss exceeds the maximum per-

¹ Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

missible under the specifications, the test shall be disqualified and another made.

ITEM 12. *The scales.*—The scales must have a capacity of not less than 300 pounds and must be sensitive to one-half of an ounce and must be tested by a standard test weight at intervals of not less than every 10 tests.

ITEM 13. *The results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick any piece weighing less than 1 pound shall be rejected.

ITEM 14. *The records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made:

1. The name of the person, firm, or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street or contract which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.
7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, breadth, and thickness of the bricks.
10. The collective weight of the 10 large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
12. The total weight of the shot charge after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel and found them right at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge.
15. The time of the beginning and ending of each test and the number of revolutions made by the barrel during the test as shown by the indicator.
16. Certificate of the operator as to number of stops and starts made in each test.
17. The initial collective weight of the 10 brick composing the charge and their collective weight after rattling.
18. The loss calculated in per cents of the initial weight; and the calculation itself.
19. The number of broken brick and remarks upon the portions which were included in the final weighing.
20. General remarks upon the test and any irregularities occurring in its execution.
21. The date upon which the test was made.
22. The location of the rattler and name of the owner.
23. The certificate of the operator that the test was made under specifications of the American Society for Testing Materials and that the record is a true record.
24. The signature of the operator or person responsible for the test.
25. The serial number of the test.

In event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicates, but the original record shall always be preserved intact and complete.

ACCEPTANCE AND REJECTION OF MATERIAL.

ITEM 15. *Basis of acceptance or rejection.*—Paving brick shall not be judged for acceptance or rejection by the results of individual tests, but by the average of not less than five tests. Where a lot of brick fails to meet the required average it shall be optional with the buyer whether the brick shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in item 16.

ITEM 16. *Range of fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variation in the brick and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than 2 per cent, then the portion of the lot represented by that test shall at once be resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than 2 per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick two or more tests exceed the permissible maximum, then the buyer may, at his option, reject the entire lot, even though the average of all the tests executed may be within the required limits.

ITEM 17. *Fixing of standards.*—The percentage of loss which may be taken as the standard will not be fixed in these regulations, and shall remain within the province of the contracting parties. For the information of the public the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	General average loss.	Maximum permissible loss.
	<i>Per cent.</i>	<i>Per cent.</i>
For brick suitable for heavy traffic.....	22	24
For brick suitable for medium traffic.....	24	26
For brick suitable for light traffic.....	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer, and should be governed by the kind and amount of traffic to be carried, and the quality of paving brick available.

ITEM 18. *Culling and retesting.*—Where under items 15 and 16 a lot or portion of a lot of brick is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

ITEM 19. *Payment of cost of testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also item 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it shall be paid by the seller, whether the material is finally accepted or rejected.

SECTION II.—VISUAL INSPECTION.

It shall be the right of the buyer to inspect the brick, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

ITEM 20. All brick which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where brick are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half brick for breaking courses and making closures, instead of breaking otherwise whole and sound brick for this purpose.

ITEM 21. All brick which are cracked in such a degree as to produce defects such as defined in item 20, either from shocks received in shipment and handling or from defective conditions of manufacture, especially in drying, burning, or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

ITEM 22. All brick which are so offsize, or so misshapen, bent, twisted, or kiln marked that they will not form a proper surface as defined by the paving specifications, or align with other brick without making joints other than those permitted in the paving specifications.

ITEM 23. All brick which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in item 2, and if in either or both tests the brick fall beyond the maximum rattler losses permitted under the specifications, then all brick having the same objectionable appearance may be excluded, and the seller must pay for the cost of the test. But if under such procedure the brick which have been tested as objectionable shall pass the rattler test, both tests falling within the permitted maximum, then the buyer can not exclude the class of material represented by this test and he shall pay for the cost of the test.

ITEM 24. All bricks which differ so markedly in color from the type or average of the shipment as to make the resultant pavement checkered or disagreeably mottled in appearance. This item shall not be held to apply to the normal variations in color which may occur in the product of one plant among brick which will meet the rattler test as referred to in items 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the brick are made, or extreme differences in manufacture.

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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER

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THE INTRINSIC VALUES OF GRAIN, COTTONSEED, FLOUR, AND SIMILAR PRODUCTS, BASED ON THE DRY-MATTER CONTENT.

By E. G. BOERNER, *Assistant in Grain Standardization.*

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INTRODUCTION.

Grain, cottonseed, flour, and other vegetable products are composed of dry matter and water. All vegetable matter contains a considerable percentage of water even when it is thoroughly air dried. The proportion of water to dry matter in the grains or cottonseed varies in each case with the season of the year, the sections of the country in which they are grown, and the way these products are handled and stored after being harvested. The minimum and maximum limits of the moisture content vary somewhat with each kind of grain, cottonseed, and their manufactured products, but are usually within the range of 10 to 30 per cent. New corn, however, frequently exceeds 30 per cent in moisture, while the small grains and cottonseed when thoroughly air dry sometimes test less than 10 per cent in moisture.

The water contained in these products, even when they are in an air-dry condition, is not considered as having any food or feeding value. Any additional moisture that it might be necessary or desirable to add to air-dry grain, flour, etc., to put it in proper condition for feeding, manufacturing, baking, etc., can be added as water at the proper time at a much less cost than to purchase it at the prices for which the products sell.

COMPARATIVE VALUES ON A DRY-MATTER BASIS.

Other things being equal, different lots of grain, cottonseed, flour, meal, etc., have an intrinsic value to the consumer, such as the live-stock feeder, the manufacturers of corn products, the cottonseed crusher, the miller of wheat, and the baker, in proportion to the amount of dry matter contained in each lot. The grain, cottonseed, and flour which contains the least moisture of course contains the greatest amount of dry matter (fig. 1) and not only has the highest intrinsic value on account of this high dry-matter content, but it is also of greater value because of its better keeping qualities while in storage. Enormous quantities of grain and cottonseed are severely damaged by molds and fermentation each year because they contain a moisture content that is too high for safe storage or transportation. As the moisture content increases, both the risk of spoilage and the

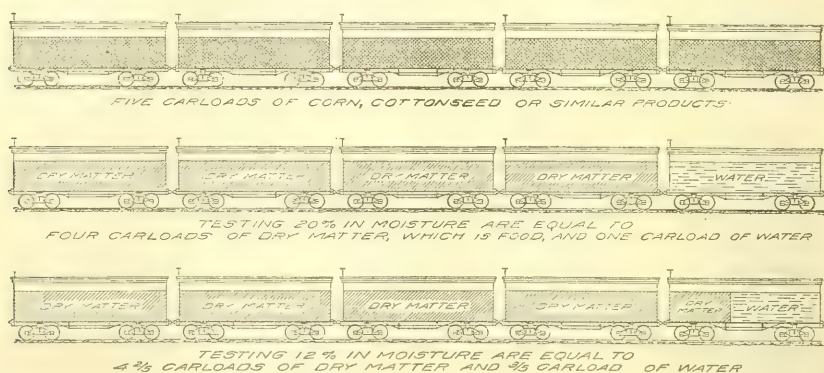


FIG. 1.—Diagram illustrating the amount of dry matter contained in five carloads of grain, cottonseed, etc., when these products test 20 per cent in moisture and when they test 12 per cent in moisture and showing that two-fifths of a carload more dry matter is present when the moisture test shows 12 per cent than when the test shows 20 per cent.

damage from fermentation when these products spoil are accelerated with each additional per cent of moisture.¹

The value of a low moisture content in grain has been recognized by the trade for many years, as is evidenced by the rules governing the grading of grain, which specified that the grain to receive one of the higher grades must be "dry"; for a lower grade "reasonably dry" was sufficient, and the lowest grades allowed "damp" or "wet" grain. These quoted terms, of course, are very indefinite and allow too much elasticity in their interpretation by the various interested parties. In comparatively recent years these indefinite terms have been converted into definite percentages as applied to certain grades. The Grain Dealers' National Association was the first grain organization to place the factor of moisture in the grading of grain on a percentage basis. In 1906 this association adopted grade rules defining

¹ For the results of experiments to determine the relation of different moisture contents to deterioration in corn, see Bureau of Plant Industry Circular 55, "American Export Corn (Maize) in Europe," by J. D. Shanahan, C. E. Leighty, and E. G. Boerner; also U. S. Department of Agriculture Bulletin 48, entitled "The Shrinkage of Shelled Corn while in Cars in Transit," by J. W. T. Duvel and Laurel Duval.

definite maximum limits of moisture for the various grades of corn. These grades were adopted by many of the State grain-inspection departments and grain exchanges and resulted in the wide adoption of the quick method for the determination of the moisture content of grain which was devised in the Department of Agriculture.¹ In 1914, the Department of Agriculture promulgated grades for commercial corn and fixed definite maximum limits of moisture which each of the six numerical grades might contain.² These grades have been adopted and are now in force in most of the corn markets in the United States. The pure-food laws in some States also have certain regulations dealing with the amount of moisture which grain and flour may contain in order to enter the State.

U.S. GRADE	MAXIMUM MOISTURE CONTENT— PER CENT	1000 BUSHEL OF CORN		COMPARA- TIVE VALUE OF DRY MATTER ^(a)	VALUE GREATER (+) OR LESS (-) THAN N°3 GRADE
		DRY MATTER—LBS.	WATER LBS.		
N° 1	14.0	48160	7840	\$729.70	+ \$29.70
N° 2	15.5	47320	8680	717.00	+ 17.00
N° 3	17.5	46200	9800	700.00	0
N° 4	19.5	45080	10920	683.00	- 17.00
N° 5	21.5	43960	12040	666.00	- 34.00
N° 6	23.0	43120	12880	653.30	- 46.70

(a) MOVING THE DECIMAL POINT ONE PLACE TO THE LEFT GIVES THE VALUE IN CENTS PER BUSHEL

NOTE: EACH 1% OF DRY MATTER EQUALS .84848* CENTS PER BUSHEL

FIG. 2.—Diagram showing the amount of dry matter and of water contained in 1,000 bushels of corn testing the maximum percentage in moisture allowed in the six numerical grades for commercial corn and also the comparative value of the dry matter in 1,000 bushels of each grade when No. 3 corn is worth 70 cents per bushel.

When a unit of weight of grain, cottonseed, etc., which contains excess moisture dries out naturally or is artificially dried to a lower moisture content, some of the water is lost but all of the dry matter is retained, and as only the dry matter is considered as having any value the total value will be the same after drying that it was before drying. The weight, however, will have been reduced through the loss in moisture.

Figure 2 shows the comparative values by grades of the dry matter contained in a carload of 1,000 bushels of corn testing the maximum limits in moisture allowed in the Government grades for commercial corn when No. 3 corn is considered as being worth 70 cents per bushel.

¹ For a description of this method and the apparatus used with it, see Bureau of Plant Industry Circular 72, entitled "A Moisture Tester for Grain and Other Substances and How to Use It," by J. W. T. Duvel.

² For an explanation of the rules for grading, see Department of Agriculture Bulletin 168, entitled "Grades for Commercial Corn," by J. W. T. Duvel.

METHOD OF DETERMINING COMPARATIVE VALUES ON A DRY-MATTER BASIS.

The comparative values given in Tables II to XII, inclusive, are based on the dry matter contained in a unit of weight. The water contained is not considered as having any intrinsic value; therefore the whole value for any unit of weight is credited to the dry matter

which it contains.

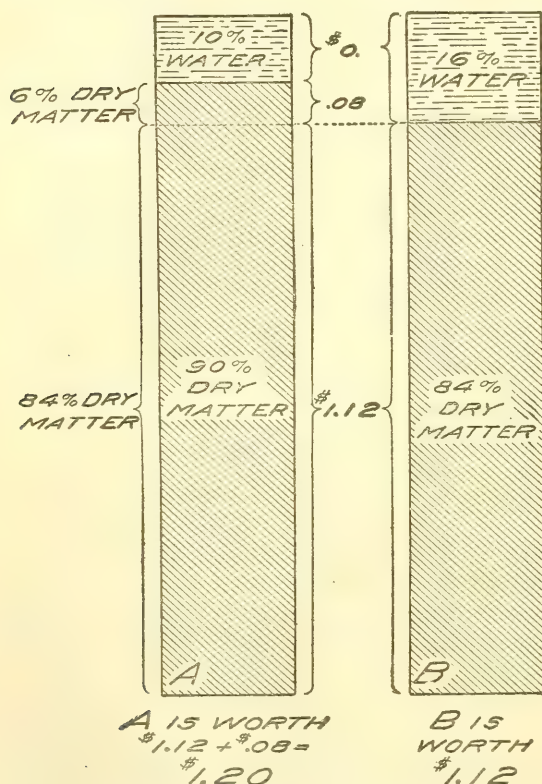
The method of arriving at comparative values of the dry matter contained in a unit of weight, when everything but moisture is considered as being equal, is explained in the solution of the following problem:

Example.—If the dry matter in a unit of weight (bushel, 100 pounds, etc.) of any grain, cottonseed, or similar product testing 10 per cent in moisture is worth \$1.20, what is the value of the dry matter in a similar unit of weight of the same product which tests 16 per cent in moisture?

A unit of weight of grain, cottonseed, or similar product testing 10 per cent in moisture contains 90 per cent of dry matter and 10 per cent of water. If the 90 per cent which is dry matter

is worth \$1.20, then each 1 per cent of the dry matter is worth $1/90$ of \$1.20, or 1.3333+ cents, and the dry matter in a similar unit testing 16 per cent in moisture and therefore having 84 per cent of dry matter is worth $84 \times 1.3333+$ cents, or \$1.12. This is graphically illustrated in figure 3.

If it is desired to extend any one of Tables II to XII, inclusive, so as to ascertain the comparative value of a unit which contains either more or less moisture than any unit shown in the table, it is only necessary to calculate the percentage of dry matter contained in this



EACH 1% OF DRY MATTER IS WORTH 1.3333 CTS.

FIG. 3.—Diagram illustrating the comparative values of the dry matter in two 1-bushel units of wheat testing 10 and 16 per cent in moisture, respectively, based on a bushel of wheat testing 10 per cent in moisture being worth \$1.20.

unit and multiply it by the value of each 1 per cent of dry matter shown in the right-hand column in the table.

Example.—If a bushel of No. 3 corn testing 17.5 per cent in moisture is worth 80 cents, what is the comparative value of a bushel of corn testing 26 per cent in moisture?

Table XI shows comparative values for units containing from 12 to 24 per cent of moisture content only, based on even money for a unit testing 17.5 per cent in moisture. Corn testing 26 per cent in moisture contains 74 per cent of dry matter and as each 1 per cent of dry matter is worth in this instance 0.9697 cents, as is shown in the right-hand column of the table, the 74 per cent of dry matter is worth 74×0.9697 cents, or 71.76 cents. Therefore, if a bushel of No. 3 corn testing 17.5 per cent in moisture is worth 80 cents, the comparative intrinsic value of a bushel of corn testing 26 per cent in moisture is 71.76 cents. The comparative value of a unit testing lower in moisture than the minimum shown in the table may be determined in a similar manner.

If it is desired to extend any one of Tables II to XII, inclusive, so as to ascertain the comparative value of any unit, the value of which is over \$1.20 but less than \$2.00, such value can be found by dividing the given value into two parts, one of which will be an even dollar and the other the fraction of the dollar, and finding the comparative value for each. The comparative value for the whole will then be the sum of these two results.

Example.—If a unit weight of grain, cottonseed, or flour testing 12 per cent in moisture is worth \$1.90, what is the comparative value of a similar unit testing 16 per cent in moisture?

Proceeding as explained above, it will be seen from Table IV that the comparative value for the \$1 part will be 95.45 cents, and the comparative value for the 90-cent part will be 85.91 cents; therefore, the comparative value for the whole will be $(95.45 + 85.91 = 181.36 \text{ cents})$ \$1.81.

Similar results can be obtained by moving the decimal point one or two places to the left, as may be necessary, and considering the figures given in these tables as dollars and cents instead of cents and fractions of a cent. According to this method, it is seen in Table IV that by moving the decimal point one place to the left, 19 cents in the 12 per cent moisture column becomes \$1.90, and the comparative value in the 16 per cent moisture column will be \$1.81, which is the same result as that obtained by the first method.

It will be noted in Tables II to XII, inclusive, that the difference in value for each 1 per cent of dry matter increases in direct proportion to the increase in the price, so that as the price of the product increases, the difference in value for each 1 per cent of dry matter or of moisture becomes of more material importance to the producer and consumer of the products under consideration.

ADVANTAGE OF BUYING AND SELLING ON A DRY-MATTER BASIS.

Buying and selling grain, flour, and cottonseed on the basis of their comparative intrinsic values depending on the amount of dry matter contained in a unit of weight is not only fair to the consumer of these agricultural products but also gives the producer an incentive for putting them on the market in a dry condition.

Much of the grain and cottonseed is sold from the farm merely as grain or cottonseed, and no premium is paid for these products when delivered with a lower moisture content than the average for the crop. The result of buying such products from the farmer on this basis is that it puts a premium on poor farming, in that it pays the farmer to sell as much water as possible at grain or cottonseed prices.

When a farmer in selling to the country elevator or other buyer delivers grain or cottonseed which contains less moisture than the average for the crop, he is entitled to a price which is higher than the average price for the crop, because grain or cottonseed which tests low in moisture has a higher intrinsic value than grain or cottonseed which tests high in moisture. By paying the farmer what his products are worth on the dry-matter basis when he delivers grain or cottonseed which contains a moisture content lower than the average for the crop, a premium is put on good farming and the result should be, with grain at least, that the farmer will have an incentive to grow an early-maturing grain which will dry out sufficiently on the farm to be in a marketable condition soon after harvesting. He will also have an incentive to store his grain and cottonseed on the farm in well-ventilated cribs and warehouses, which will facilitate natural drying and at the same time protect these products from rain and snow and thereby prevent much of the deterioration from molds, fermentation, etc., that now occurs in many cases.

OTHER FACTORS TO BE CONSIDERED.

The relation of the moisture and dry-matter contents to the intrinsic worth of grains makes Tables II to XII, inclusive, valuable in applying the factor of moisture content in the fixing of grades and also as a basis for fixing market values. In these tables, only the factors of moisture and dry matter were considered in calculating the relative values of grain on a dry-matter basis; but, while these factors are fundamental and the basis is an excellent one from which to figure intrinsic values, other factors and circumstances affecting these values must still be considered in computing market values, among which, for grain at least, can be mentioned: (1) The relative quantity of damp and therefore undesirable grain in the grain-producing States that have a surplus, or in territory contiguous to any given grain market, and the relative quantity of the market receipts that is upon inspection placed in each grade; (2) the well-

known tendency of damp grain to deteriorate in storage and in transit and the accelerated risk from such deterioration as the moisture content increases; (3) conditions relative to supply and demand at the time the grain is marketed and the relative capacity of the grain markets to absorb it or dispose of it in a damp condition at a profit; (4) weather conditions at the time of marketing and future weather conditions as affecting the condition and carrying capacity of the grain; (5) consideration of the fact that when grain must be artificially dried after being delivered to market, there is a certain extra charge for putting it through the drier and for freight on the water that must be handled; and (6) that when grain is artificially dried there is always a slight "invisible loss" in weight in the drying process. Many of these factors are of equal importance with reference to the buying and selling of cottonseed, flour, and other products.

It will therefore be seen that unless these products are purchased for immediate consumption, the relative values as given in Tables II to XII, inclusive, can not be literally applied as showing final market values, premiums, and discounts; and it was not intended that they should be so applied.

RELATION OF REDUCTION OF MOISTURE CONTENT TO SHRINKAGE IN WEIGHT.

Grain, and especially corn, frequently gets into commerce with a moisture content too high to receive one of the higher grades or to remain sound while in storage or during transportation. This is especially true in a year in which there is more than the usual amount of rainfall during the growing and harvest seasons. This condition has been partially met by the trade by the introduction of machines for artificially removing the excess moisture from the grain. These grain driers, as they are termed, are extensively used, and increasingly large amounts of grain are artificially dried by them each year.

Whether grain dries naturally or is artificially dried, the percentage of shrinkage in weight is always greater than the difference in the percentage of moisture content before and after drying, as shown by the moisture tester, unless all of the moisture is dried out when the shrinkage and the reduction in moisture are equal. For instance, if corn having an original moisture content of 23 per cent is dried so that it tests only 14 per cent, the moisture content is reduced by 9 per cent. The shrinkage in weight, however, is 10.46 per cent, as is shown in Table I.

When the original moisture content and the moisture content after drying are known, the shrinkage can be determined from Table I.

The reason for the difference in the percentage of shrinkage and the reduction of the moisture content is fully explained in Bureau of Plant Industry Circular No. 32.¹

¹ See Duvel, J. W. T. Moisture content and shrinkage in grain. U. S. Dept. Agr., Bur. Plant Indus. Cir. 32, 1909, p. 4-7.

The formula for finding the percentage of shrinkage corresponding to any reduction in moisture content is as follows:

$$100 - \left(\left\{ \begin{array}{c} \text{Percentage of} \\ \text{dry matter} \\ \text{after drying} \end{array} \right\} : \left\{ \begin{array}{c} \text{Percentage of} \\ \text{dry matter} \\ \text{before drying} \end{array} \right\} :: 100 : x \right) = \left\{ \begin{array}{c} \text{Percentage of} \\ \text{shrinkage.} \end{array} \right.$$

Example.—Find the percentage of shrinkage when wheat has been dried from 18 per cent moisture content to 12 per cent moisture content.

Solution: $100 - (88 : 82 :: 100 : x) = (100 - 93.18)$, which equals 6.82.

In this case the moisture content was reduced by 6 per cent and the shrinkage in weight was 6.82 per cent.

When the original weight and the moisture content before and after drying are known and it is desired to find the final weight, or, in other words, the weight of the dried material, it can be obtained by the formula—

$$\left\{ \begin{array}{c} \text{Percentage of} \\ \text{dry matter} \\ \text{after drying} \end{array} \right\} : \left\{ \begin{array}{c} \text{Percentage of} \\ \text{dry matter} \\ \text{before drying} \end{array} \right\} :: \left\{ \begin{array}{c} \text{Original} \\ \text{weight.} \end{array} \right\} : \left\{ \begin{array}{c} \text{Final} \\ \text{weight.} \end{array} \right.$$

Example.—If 2,000 pounds of grain containing 18 per cent of moisture has been dried and the grain tested 12 per cent of moisture after drying, what is the weight of the grain after drying?

Applying the above formula gives—

$$(88 : 82 :: 2,000 : x) = (164000 \div 88), \text{ which equals } 1,863.6.$$

Therefore, the grain after drying weighed 1,863.6 pounds.

EXPLANATION OF TABLES.

Table I shows the percentage of shrinkage in weight corresponding to definite reductions in the moisture content.

Tables II to XII, inclusive, show the comparative values on a dry-matter basis of grain, cottonseed, and other products containing various percentages of moisture.

Tables II to IX, inclusive, are applicable to all grains, cottonseed, flour, and similar products, and give the comparative values for the dry matter in a unit containing from 10 to 24 per cent of moisture. These tables are based on even money for the units containing 10 to 17 per cent of moisture, respectively.

Tables X and XI are more particularly applicable to shelled corn and give the comparative values for the dry matter in a unit containing from 12 to 24 per cent of moisture. These tables are based on even money for units containing the maximum moisture allowed in the Government grades for No. 2 and No. 3 corn, respectively.

Table XII gives the comparative values, by grades, of a unit of corn containing the maximum moisture allowed in each of the six numerical grades established by the Government.

Tables showing the comparative values of a unit of weight of grain on a dry-matter basis when applied to corn are applicable to shelled corn only. In ear corn, the cobs at the time of harvest test higher in moisture than the kernels, but during storage the cobs dry out faster than the kernels and contain less moisture than the kernels when the corn is in an air-dry condition.

TABLE I.—Percentage of shrinkage in weight of grain, cottonseed, flour, etc., when the loss in moisture and the original moisture content are known.

Loss in moisture.	Original moisture content (per cent).													
	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
1 per cent.	1.07	1.09	1.10	1.11	1.12	1.14	1.15	1.16	1.18	1.19	1.20	1.22	1.23	1.25
2 per cent.	2.13	2.15	2.17	2.20	2.22	2.25	2.27	2.30	2.32	2.35	2.38	2.41	2.44	2.47
3 per cent.	3.16	3.19	3.22	3.26	3.30	3.33	3.77	3.41	3.45	3.49	3.53	3.57	3.61	3.66
4 per cent.	4.17	4.21	4.25	4.30	4.35	4.39	4.44	4.49	4.54	4.60	4.65	4.70	4.76	4.82
5 per cent.	5.15	5.21	5.26	5.32	5.38	5.43	5.49	5.55	5.62	5.68	5.75	5.81	5.88	5.95
6 per cent.	6.12	6.18	6.25	6.31	6.38	6.45	6.52	6.59	6.67	6.74	6.82	6.90	6.98	7.06
7 per cent.	7.07	7.14	7.22	7.29	7.37	7.45	7.53	7.61	7.69	7.78	7.86	7.95	8.04	8.14
8 per cent.	8.00	8.08	8.16	8.25	8.33	8.42	8.51	8.60	8.69	8.79	8.89	8.99	9.09	9.19
9 per cent. ....	.....	9.00	9.09	9.18	9.28	9.37	9.47	9.57	9.68	9.78	9.89	10.00	10.11	10.23
10 per cent. ....	.....	.....	10.00	10.10	10.20	10.31	10.42	10.53	10.64	10.75	10.87	10.99	11.11	11.23
11 per cent. ....	.....	.....	.....	11.00	11.11	11.22	11.34	11.46	11.58	11.70	11.83	11.96	12.09	12.22
12 per cent. ....	.....	.....	.....	.....	12.00	12.12	12.24	12.37	12.50	12.63	12.76	12.90	13.04	13.19
13 per cent. ....	.....	.....	.....	.....	.....	13.00	13.13	13.26	13.40	13.54	13.68	13.83	13.98	14.13
14 per cent. ....	.....	.....	.....	.....	.....	.....	14.00	14.14	14.28	14.43	14.58	14.74	14.89	15.05
15 per cent. ....	.....	.....	.....	.....	.....	.....	.....	15.00	15.15	15.31	15.46	15.62	15.79	15.96
16 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	16.00	16.16	16.33	16.49	16.67	16.84
17 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.00	17.17	17.35	17.52	17.71
18 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.00	18.18	18.37	18.56
19 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.00	19.19	19.39
20 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.00	20.20
21 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	21.00
	22	23	24	25	26	27	28	29	30	31	32	33	34	35
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
1 per cent.	1.26	1.28	1.30	1.31	1.33	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.51
2 per cent.	2.50	2.53	2.56	2.60	2.63	2.67	2.70	2.74	2.78	2.82	2.86	2.90	2.94	2.98
3 per cent.	3.70	3.75	3.80	3.85	3.90	3.95	4.00	4.05	4.11	4.17	4.22	4.28	4.35	4.41
4 per cent.	4.88	4.94	5.00	5.06	5.13	5.19	5.26	5.33	5.40	5.48	5.55	5.63	5.71	5.80
5 per cent.	6.02	6.10	6.17	6.25	6.33	6.41	6.49	6.58	6.67	6.76	6.85	6.94	7.04	7.14
6 per cent.	7.14	7.23	7.32	7.41	7.50	7.59	7.69	7.79	7.89	8.00	8.11	8.22	8.33	8.45
7 per cent.	8.23	8.33	8.43	8.54	8.64	8.75	8.86	8.97	9.09	9.21	9.33	9.46	9.59	9.72
8 per cent.	9.30	9.41	9.52	9.64	9.76	9.88	10.00	10.13	10.26	10.39	10.53	10.67	10.81	10.96
9 per cent.	10.34	10.46	10.59	10.71	10.84	10.97	11.11	11.25	11.39	11.54	11.69	11.84	12.00	12.16
10 per cent.	11.36	11.49	11.63	11.76	11.90	12.05	12.19	12.34	12.50	12.66	12.82	12.99	13.16	13.33
11 per cent.	12.35	12.50	12.64	12.79	12.94	13.09	13.25	13.41	13.58	13.75	13.92	14.10	14.28	14.47
12 per cent.	13.33	13.48	13.64	13.79	13.95	14.12	14.28	14.46	14.63	14.81	15.00	15.19	15.38	15.58
13 per cent.	14.28	14.44	14.61	14.77	14.94	15.12	15.29	15.48	15.66	15.85	16.05	16.25	16.45	16.67
14 per cent.	15.22	15.38	15.55	15.73	15.91	16.09	16.28	16.47	16.67	16.87	17.07	17.28	17.50	17.72
15 per cent.	16.13	16.30	16.48	16.67	16.85	17.04	17.24	17.44	17.65	17.86	18.07	18.29	18.52	18.75
16 per cent.	17.02	17.20	17.39	17.58	17.78	17.98	18.18	18.39	18.60	18.82	19.05	19.28	19.51	19.75
17 per cent.	17.89	18.08	18.28	18.48	18.68	18.89	19.10	19.32	19.54	19.77	20.00	20.24	20.48	20.73
18 per cent.	18.75	18.95	19.15	19.35	19.56	19.78	20.00	20.22	20.45	20.69	20.93	21.18	21.43	21.69
19 per cent.	19.59	19.79	20.00	20.21	20.43	20.65	20.88	21.11	21.35	21.59	21.84	22.09	22.35	22.62
20 per cent.	20.41	20.62	20.83	21.05	21.28	21.50	21.74	21.98	22.22	22.47	22.73	22.99	23.25	23.53
21 per cent.	21.21	21.43	21.65	21.87	22.10	22.34	22.58	22.83	23.08	23.33	23.59	23.86	24.14	24.42
22 per cent.	22.00	22.22	22.45	22.68	22.92	23.16	23.40	23.65	23.91	24.17	24.44	24.72	25.00	25.29
23 per cent. ....	.....	23.00	23.23	23.47	23.71	23.96	24.21	24.47	24.73	25.00	25.27	25.55	25.84	26.14
24 per cent. ....	.....	.....	24.00	24.24	24.49	24.74	25.00	25.26	25.53	25.81	26.09	26.37	26.67	26.97
25 per cent. ....	.....	.....	.....	25.00	25.25	25.51	25.77	26.04	26.31	26.59	26.88	27.17	27.47	27.78
26 per cent. ....	.....	.....	.....	.....	26.00	26.26	26.53	26.80	27.08	27.37	27.66	27.96	28.26	28.57
27 per cent. ....	.....	.....	.....	.....	.....	27.00	27.27	27.55	27.83	28.12	28.42	28.72	29.03	29.35
28 per cent. ....	.....	.....	.....	.....	.....	.....	28.00	28.28	28.57	28.86	29.17	29.47	29.79	30.11
29 per cent. ....	.....	.....	.....	.....	.....	.....	.....	29.00	29.29	29.59	29.90	30.21	30.53	30.85
30 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	30.00	30.30	30.61	30.93	31.25	31.58
31 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	31.00	31.31	31.63	31.96	32.29
32 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	32.00	32.32	32.65	32.99
33 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	33.00	33.33	33.67
34 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.00	34.34
35 per cent. ....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	35.00

TABLE II.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 10 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
1	0.99	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	0.85	0.84	0.01111+
2	1.98	1.95	1.93	1.91	1.89	1.87	1.84	1.82	1.80	1.78	1.75	1.73	1.71	1.69	.02222+
3	2.97	2.93	2.90	2.87	2.83	2.80	2.77	2.73	2.70	2.67	2.63	2.60	2.57	2.53	.03333+
4	3.95	3.91	3.87	3.82	3.78	3.73	3.69	3.64	3.60	3.55	3.51	3.47	3.42	3.38	.04444+
5	4.94	4.89	4.83	4.78	4.72	4.67	4.61	4.55	4.50	4.44	4.39	4.33	4.28	4.22	.05555+
6	5.93	5.87	5.80	5.73	5.67	5.60	5.53	5.47	5.40	5.33	5.27	5.20	5.13	5.07	.06667—
7	6.92	6.84	6.77	6.69	6.61	6.53	6.45	6.38	6.30	6.22	6.14	6.07	5.99	5.91	.07778—
8	7.91	7.82	7.73	7.64	7.55	7.47	7.38	7.29	7.20	7.11	7.02	6.93	6.84	6.75	.08889—
9	8.90	8.80	8.70	8.60	8.50	8.40	8.30	8.20	8.10	8.00	7.90	7.80	7.70	7.60	.10000—
10	9.89	9.78	9.67	9.55	9.44	9.33	9.22	9.11	9.00	8.89	8.78	8.67	8.55	8.44	.11111+
11	10.88	10.75	10.63	10.51	10.39	10.27	10.14	10.02	9.90	9.78	9.65	9.53	9.41	9.29	.12222+
12	11.87	11.73	11.60	11.47	11.33	11.20	11.07	10.93	10.80	10.67	10.53	10.40	10.27	10.13	.13333+
13	12.85	12.71	12.57	12.42	12.28	12.13	11.99	11.84	11.70	11.55	11.41	11.27	11.12	10.98	.14444+
14	13.84	13.69	13.53	13.38	13.22	13.07	12.91	12.75	12.60	12.44	12.29	12.13	11.98	11.82	.15555+
15	14.83	14.67	14.50	14.33	14.17	14.00	13.83	13.67	13.50	13.33	13.17	13.00	12.83	12.67	.16667—
16	15.82	15.64	15.47	15.29	15.11	14.93	14.75	14.58	14.40	14.22	14.04	13.87	13.69	13.51	.17778—
17	16.81	16.62	16.43	16.24	16.05	15.87	15.68	15.49	15.30	15.11	14.92	14.73	14.54	14.35	.18889—
18	17.80	17.60	17.40	17.20	17.00	16.80	16.60	16.40	16.20	16.00	15.80	15.60	15.40	15.20	.20000—
19	18.79	18.58	18.37	18.15	17.94	17.73	17.52	17.31	17.10	16.89	16.68	16.47	16.25	16.04	.21111+
20	19.78	19.55	19.33	19.11	18.89	18.67	18.44	18.22	18.00	17.78	17.55	17.33	17.11	16.89	.22222+
21	20.77	20.53	20.30	20.07	19.83	19.60	19.37	19.13	18.90	18.67	18.43	18.20	17.97	17.73	.23333+
22	21.75	21.51	21.27	21.02	20.78	20.53	20.29	20.04	19.80	19.55	19.31	19.07	18.82	18.58	.24444+
23	22.74	22.49	22.23	21.98	21.72	21.47	21.21	20.95	20.70	20.44	20.19	19.93	19.68	19.42	.25555+
24	23.73	23.47	23.20	22.93	22.67	22.40	22.13	21.87	21.60	21.33	21.07	20.80	20.53	20.27	.26667—
25	24.72	24.44	24.17	23.89	23.61	23.33	23.05	22.78	22.50	22.22	21.94	21.67	21.39	21.11	.27778—
26	25.71	25.42	25.13	24.84	24.55	24.27	23.98	23.69	23.40	23.11	22.82	22.53	22.24	21.95	.28889—
27	26.70	26.40	26.10	25.80	25.50	25.20	24.90	24.60	24.30	24.00	23.70	23.40	23.10	22.80	.30000—
28	27.69	27.38	27.07	26.75	26.44	26.13	25.82	25.51	25.20	24.89	24.58	24.27	23.95	23.64	.31111+
29	28.68	28.35	28.03	27.71	27.39	27.07	26.74	26.42	26.10	25.78	25.45	25.13	24.81	24.49	.32222+
30	29.67	29.33	29.00	28.67	28.33	28.00	27.67	27.33	27.00	26.67	26.33	26.00	25.67	25.33	.33333+
31	30.65	30.31	29.97	29.62	29.28	28.93	28.59	28.24	27.90	27.55	27.21	26.87	26.52	26.18	.34444+
32	31.64	31.29	30.94	30.58	30.22	29.87	29.51	29.15	28.80	28.44	28.09	27.73	27.38	27.02	.35555+
33	32.63	32.27	31.90	31.53	31.17	30.80	30.43	30.07	29.70	29.33	28.97	28.60	28.23	27.87	.36667—
34	33.62	33.24	32.87	32.49	32.11	31.73	31.35	30.98	30.60	30.22	29.84	29.47	29.09	28.71	.37778—
35	34.61	34.22	33.83	33.44	33.05	32.67	32.28	31.89	31.50	31.11	30.72	30.33	29.94	29.55	.38889—
36	35.60	35.20	34.80	34.40	34.00	33.60	33.20	32.80	32.40	32.00	31.60	31.20	30.80	30.40	.40000—
37	36.59	36.18	35.77	35.35	34.94	34.53	34.12	33.71	33.30	32.89	32.48	32.07	31.65	31.24	.41111+
38	37.58	37.15	36.73	36.31	35.89	35.47	35.04	34.62	34.20	33.78	33.35	32.93	32.51	32.09	.42222+
39	38.57	38.13	37.70	37.27	36.83	36.40	35.97	35.53	35.10	34.67	34.23	33.80	33.37	32.93	.43333+
40	39.55	39.11	38.67	38.22	37.77	37.33	36.89	36.44	36.00	35.55	35.11	34.67	34.22	33.78	.44444+
41	40.54	40.09	39.63	39.18	38.72	38.27	37.81	37.35	36.90	36.44	35.99	35.53	35.08	34.62	.45555+
42	41.53	41.07	40.60	40.13	39.67	39.20	38.73	38.27	37.80	37.33	36.87	36.40	35.93	35.47	.46667—
43	42.52	42.04	41.57	41.09	40.61	40.13	39.65	39.18	38.70	38.22	37.74	37.27	36.79	36.31	.47778—
44	43.51	43.02	42.54	42.05	41.55	41.07	40.58	40.09	39.60	39.11	38.62	38.13	37.64	37.15	.48889—
45	44.50	44.00	43.50	43.00	42.50	42.00	41.50	41.00	40.50	40.00	39.50	39.00	38.50	38.00	.50000—
46	45.49	44.98	44.47	43.95	43.43	42.91	42.42	41.91	41.40	40.89	40.38	39.87	39.35	38.84	.51111+
47	46.48	45.95	45.43	44.91	44.39	43.87	43.34	42.82	42.30	41.78	41.25	40.73	40.21	39.69	.52222+
48	47.47	46.93	46.40	45.87	45.33	44.80	44.27	43.73	43.20	42.67	42.13	41.60	41.07	40.53	.53333+
49	48.45	47.91	47.37	46.82	46.28	45.73	45.19	44.64	44.10	43.55	43.01	42.47	41.92	41.38	.54444+
50	49.44	48.89	48.33	47.78	47.22	46.67	46.11	45.55	45.00	44.44	43.89	43.33	42.78	42.22	.55555+
51	50.43	49.87	49.30	48.73	48.17	47.60	47.03	46.47	45.90	45.33	44.77	44.20	43.63	43.07	.56667—
52	51.42	50.84	50.27	49.69	49.11	48.53	47.95	47.38	46.80	46.22	45.64	45.07	44.49	43.91	.57778—
53	52.41	51.82	51.23	50.64	50.05	49.47	48.88	48.29	47.70	47.11	46.52	45.93	45.34	44.75	.58889—
54	53.40	52.80	52.20	51.60	51.00	50.40	49.80	49.20	48.60	48.00	47.40	46.80	46.20	45.60	.60000—
55	54.39	53.78	53.17	52.55	51.94	51.33	50.72	50.11	49.50	48.89	48.28	47.67	47.05	46.44	.61111+
56	55.38	54.75	54.13	53.51	52.89	52.27	51.64	51.02	50.40	49.78	49.15	48.53	47.91	47.29	.62222+
57	56.37	55.73	55.10	54.47	53.83	53.20	52.57	51.93	51.30	50.67	50.03	49.40	48.77	48.13	.63333+
58	57.35	56.71	56.07	55.42	54.78	54.13	53.49	52.84	52.20	51.55	50.91	50.27	49.62	48.98	.64444+
59	58.34	57.69	57.04	56.38	55.72	55.07	54.41	53.75	53.10	52.44	51.79	51.13	50.48	49.82	.65555+
60	59.33	58.67	58.00	57.33	56.67	56.00	55.33	54.67	54.00	53.33	52.67	52.00	51.33	50.67	.66667—

TABLE II.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 10 per cent in moisture is in even cents—Continued.

*Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
61	60.32	59.64	58.97	58.29	57.61	56.93	56.25	55.58	54.90	54.22	53.54	52.87	52.19	51.51	0.67778—
62	61.31	60.62	59.93	59.24	58.55	57.87	57.18	56.49	55.80	55.11	54.42	53.73	53.04	52.35	.68889—
63	62.30	61.60	60.90	60.20	59.50	58.80	58.10	57.40	56.70	56.00	55.30	54.60	53.90	53.20	.70000—
64	63.29	62.58	61.87	61.15	60.44	59.73	59.02	58.31	57.60	56.89	56.18	55.47	54.75	54.04	.71111+
65	64.28	63.55	62.83	62.11	61.39	60.67	59.94	59.22	58.50	57.78	57.05	56.33	55.61	54.89	.72222+
66	65.27	64.53	63.80	63.07	62.33	61.60	60.87	60.13	59.40	58.67	57.93	57.20	56.47	55.73	.73333+
67	66.25	65.51	64.77	64.02	63.28	62.53	61.79	61.04	60.30	59.55	58.81	58.07	57.32	56.58	.74444+
68	67.24	66.49	65.73	64.98	64.22	63.47	62.71	61.95	61.20	60.44	59.69	58.93	58.18	57.42	.75555+
69	68.23	67.47	66.70	65.93	65.17	64.40	63.63	62.87	62.10	61.33	60.57	59.80	59.03	58.27	.76667—
70	69.22	68.44	67.67	66.89	66.11	65.33	64.55	63.78	63.00	62.22	61.44	60.67	59.89	59.11	.77778—
71	70.21	69.42	68.63	67.84	67.05	66.27	65.48	64.69	63.90	63.11	62.32	61.53	60.74	59.95	.78889—
72	71.20	70.40	69.60	68.80	68.00	67.20	66.40	65.60	64.80	64.00	63.20	62.40	61.60	60.80	.80000—
73	72.19	71.38	70.57	69.75	68.94	68.13	67.32	66.51	65.70	64.89	64.08	63.27	62.45	61.64	.81111+
74	73.18	72.35	71.53	70.71	69.89	69.07	68.24	67.42	66.60	65.78	64.95	64.13	63.31	62.49	.82222+
75	74.17	73.33	72.50	71.67	70.83	70.00	69.17	68.33	67.50	66.67	65.83	65.00	64.17	63.33	.83333+
76	75.15	74.31	73.47	72.62	71.78	70.93	70.09	69.24	68.40	67.55	66.71	65.87	65.02	64.18	.84444+
77	76.14	75.29	74.43	73.58	72.72	71.87	71.01	70.15	69.30	68.44	67.59	66.73	65.88	65.02	.85555+
78	77.13	76.27	75.40	74.53	73.67	72.80	71.93	71.07	70.20	69.33	68.47	67.60	66.73	65.87	.86667—
79	78.12	77.24	76.37	75.49	74.61	73.73	72.85	71.98	71.10	70.22	69.34	68.47	67.59	66.71	.87778—
80	79.11	78.22	77.33	76.44	75.55	74.67	73.78	72.89	72.00	71.11	70.22	69.33	68.44	67.55	.88889—
81	80.10	79.20	78.30	77.40	76.50	75.60	74.70	73.80	72.90	72.00	71.10	70.20	69.30	68.40	.90000—
82	81.09	80.18	79.27	78.35	77.44	76.53	75.62	74.71	73.80	72.89	71.98	71.07	70.15	69.24	.91111+
83	82.08	81.15	80.23	79.31	78.39	77.47	76.54	75.62	74.70	73.78	72.85	71.93	71.01	70.09	.92222+
84	83.07	82.13	81.20	80.27	79.33	78.40	77.47	76.53	75.60	74.67	73.73	72.80	71.87	70.93	.93333+
85	84.05	83.11	82.17	81.22	80.28	79.33	78.39	77.44	76.50	75.55	74.61	73.67	72.72	71.78	.94444+
86	85.04	84.09	83.13	82.18	81.22	80.27	79.31	78.35	77.40	76.44	75.49	74.53	73.58	72.62	.95555+
87	86.03	85.07	84.10	83.13	82.17	81.20	80.23	79.27	78.30	77.33	76.37	75.40	74.43	73.47	.96667—
88	87.02	86.04	85.07	84.09	83.11	82.13	81.15	80.18	79.20	78.22	77.24	76.27	75.29	74.31	.97778—
89	88.01	87.02	86.03	85.04	84.05	83.07	82.08	81.09	80.10	79.11	78.12	77.13	76.14	75.15	.98889—
90	89.00	88.00	87.00	86.00	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000—
91	89.99	88.98	87.97	86.95	85.94	84.93	83.92	82.91	81.90	80.89	79.88	78.87	77.85	76.84	1.01111+
92	90.98	89.95	88.93	87.91	86.89	85.87	84.84	83.82	82.80	81.78	80.75	79.73	78.71	77.69	1.02222+
93	91.97	90.93	89.90	88.87	87.83	86.80	85.77	84.73	83.70	82.67	81.63	80.60	79.57	78.53	1.03333+
94	92.95	91.91	90.87	89.82	88.78	87.73	86.69	85.64	84.60	83.55	82.51	81.47	80.42	79.38	1.04444+
95	93.94	92.89	91.83	90.78	89.72	88.67	87.61	86.55	85.50	84.44	83.39	82.33	81.28	80.22	1.05555+
96	94.93	93.87	92.80	91.73	90.67	89.60	88.53	87.47	86.40	85.33	84.27	83.20	82.13	81.07	1.06667—
97	95.92	94.84	93.77	92.69	91.61	90.53	89.45	88.38	87.30	86.22	85.14	84.07	82.99	81.91	1.07778—
98	96.91	95.82	94.73	93.64	92.55	91.47	90.38	89.29	88.20	87.11	86.02	84.93	83.84	82.75	1.08889—
99	97.90	96.80	95.70	94.60	93.50	92.40	91.30	90.20	89.10	88.00	86.90	85.80	84.70	83.60	1.10000—
100	98.89	97.78	96.67	95.55	94.44	93.33	92.22	91.11	90.00	88.89	87.78	86.67	85.55	84.44	1.11111+
101	99.88	98.75	97.63	96.51	95.39	94.27	93.14	92.02	90.90	89.78	88.65	87.53	86.41	85.29	1.12222+
102	100.87	99.73	98.60	97.47	96.33	95.20	94.07	92.93	91.80	90.67	89.53	88.40	87.27	86.13	1.13333+
103	101.85	100.71	99.57	98.42	97.28	96.13	94.99	93.84	92.70	91.55	90.41	89.27	88.12	86.98	1.14444+
104	102.84	101.69	100.53	99.38	98.22	97.07	95.91	94.75	93.60	92.44	91.29	90.13	88.98	87.82	1.15555+
105	103.83	102.67	101.50	100.33	99.17	98.00	96.83	95.67	94.50	93.33	92.17	91.00	89.83	88.67	1.16667—
106	104.82	103.64	102.47	101.29	100.11	98.93	97.75	96.58	95.40	94.22	93.04	91.87	90.69	89.51	1.17778—
107	105.81	104.62	103.43	102.24	101.05	99.87	98.68	97.49	96.30	95.11	93.92	92.73	91.54	90.35	1.18889—
108	106.80	105.60	104.40	103.20	102.00	100.80	99.60	98.40	97.20	96.00	94.80	93.60	92.40	91.20	1.20000—
109	107.79	106.58	105.37	104.15	102.94	101.73	100.52	99.31	98.10	96.89	95.68	94.47	93.25	92.04	1.21111+
110	108.78	107.55	106.33	105.11	103.89	102.67	101.44	100.22	99.00	97.78	96.55	95.33	94.11	92.89	1.22222+
111	109.77	108.53	107.30	106.07	104.83	103.60	102.37	101.13	99.90	98.67	97.43	96.20	94.97	93.73	1.23333+
112	110.75	109.51	108.27	107.02	105.78	104.53	103.29	102.04	100.80	99.55	98.31	97.07	95.82	94.58	1.24444+
113	111.74	110.49	109.23	107.98	106.72	105.47	104.21	102.95	101.70	100.44	99.19	97.93	96.68	95.42	1.25555+
114	112.73	111.47	110.20	108.93	107.67	106.40	105.13	103.87	102.60	101.33	100.07	98.80	97.53	96.27	1.26667—
115	113.72	112.44	111.17	109.89	108.61	107.33	106.05	104.78	103.50	102.22	100.94	99.67	98.39	97.11	1.27778—
116	114.71	113.42	112.13	110.84	109.55	108.26	106.98	105.69	104.40	103.11	101.82	100.53	99.24	97.95	1.28889—
117	115.70	114.40	113.10	111.80	110.50	109.20	107.90	106.60	105.30	104.00	102.70	101.40	100.10	98.80	1.30000—
118	116.69	115.38	114.07	112.75	111.44	110.13	108.82	107.51	106.20	104.89	103.58	102.27	100.95	99.64	1.31111+
119	117.68	116.35	115.03	113.71	112.39	111.07	109.74	108.42	107.10	105.78	104.45	103.13	101.81	100.49	1.32222+
120	118.67	117.33	116.00	114.67	113.33	112.00	110.67	109.33	108.00	106.67	105.33	104.00	102.67	101.33	1.33333+

TABLE III.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 11 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
1.01	1	0.99	0.98	0.97	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.86	0.85	0.01123+
2.02	2	1.98	1.95	1.93	1.91	1.89	1.86	1.84	1.82	1.80	1.77	1.75	1.73	1.71	.02247+
3.03	3	2.97	2.93	2.90	2.86	2.83	2.80	2.76	2.73	2.70	2.66	2.63	2.59	2.56	.03371+
4.04	4	3.95	3.91	3.86	3.82	3.77	3.73	3.68	3.64	3.59	3.55	3.50	3.46	3.41	.04494+
5.06	5	4.94	4.89	4.83	4.77	4.72	4.66	4.61	4.55	4.49	4.44	4.38	4.32	4.27	.05618-
6.07	6	5.93	5.86	5.80	5.73	5.66	5.59	5.53	5.46	5.39	5.32	5.26	5.19	5.12	.06741+
7.08	7	6.92	6.84	6.76	6.68	6.61	6.53	6.45	6.37	6.29	6.21	6.13	6.06	5.98	.07865+
8.09	8	7.91	7.82	7.73	7.64	7.55	7.46	7.37	7.28	7.19	7.10	7.01	6.92	6.83	.08989+
9.10	9	8.90	8.80	8.70	8.58	8.49	8.39	8.29	8.19	8.09	7.99	7.89	7.79	7.68	.10112+
10.11	10	9.89	9.77	9.66	9.55	9.44	9.32	9.21	9.10	8.99	8.88	8.76	8.65	8.54	.11236-
11.12	11	10.87	10.75	10.63	10.50	10.38	10.26	10.13	10.01	9.89	9.76	9.64	9.52	9.39	.12359+
12.13	12	11.86	11.73	11.59	11.46	11.32	11.19	11.06	10.92	10.79	10.65	10.52	10.38	10.25	.13483+
13.15	13	12.85	12.71	12.56	12.41	12.27	12.12	11.98	11.83	11.68	11.54	11.39	11.25	11.10	.14607-
14.16	14	13.84	13.68	13.53	13.37	13.21	13.05	12.90	12.74	12.58	12.43	12.27	12.11	11.95	.15730+
15.17	15	14.83	14.66	14.49	14.32	14.16	13.99	13.82	13.65	13.48	13.31	13.15	12.98	12.81	.16854-
16.18	16	15.82	15.64	15.46	15.28	15.10	14.92	14.74	14.56	14.38	14.20	14.02	13.84	13.66	.17977+
17.19	17	16.81	16.62	16.43	16.23	16.04	15.85	15.66	15.47	15.28	15.09	14.90	14.71	14.52	.19101+
18.20	18	17.80	17.59	17.39	17.19	16.99	16.79	16.58	16.38	16.18	15.98	15.77	15.57	15.37	.20225-
19.21	19	18.79	18.57	18.36	18.14	17.93	17.72	17.50	17.29	17.08	16.86	16.65	16.44	16.22	.21348+
20.22	20	19.77	19.55	19.32	19.10	18.88	18.65	18.43	18.20	17.98	17.75	17.53	17.30	17.08	.22472-
21.23	21	20.76	20.53	20.29	20.05	19.82	19.58	19.35	19.11	18.88	18.64	18.40	18.17	17.93	.23595+
22.25	22	21.75	21.50	21.26	21.01	20.76	20.52	20.27	20.01	19.77	19.53	19.28	19.03	18.79	.24719+
23.26	23	22.74	22.48	22.22	21.97	21.71	21.45	21.19	20.93	20.67	20.41	20.16	19.90	19.64	.25843+
24.27	24	23.73	23.46	23.19	22.92	22.65	22.38	22.11	21.84	21.57	21.30	21.03	20.76	20.49	.26966+
25.28	25	24.72	24.44	24.16	23.88	23.59	23.31	23.03	22.75	22.47	22.19	21.91	21.63	21.35	.28090-
26.29	26	25.71	25.41	25.12	24.83	24.54	24.25	23.95	23.66	23.37	23.08	22.79	22.49	22.20	.29213+
27.30	27	26.70	26.39	26.09	25.79	25.48	25.18	24.88	24.57	24.27	23.97	23.66	23.36	23.06	.30337+
28.31	28	27.68	27.37	27.06	26.74	26.43	26.11	25.80	25.48	25.17	24.85	24.54	24.22	23.91	.31461-
29.32	29	28.67	28.35	28.02	27.70	27.37	27.04	26.72	26.39	26.07	25.74	25.41	25.09	24.76	.32584+
30.34	30	29.66	29.32	28.99	28.65	28.31	27.98	27.64	27.30	26.97	26.63	26.29	25.95	25.62	.33708-
31.35	31	30.65	30.30	29.95	29.61	29.26	28.91	28.56	28.21	27.86	27.51	27.17	26.82	26.47	.34831+
32.36	32	31.64	31.28	30.92	30.56	30.20	29.84	29.48	29.12	28.76	28.40	28.04	27.68	27.32	.35955+
33.37	33	32.63	32.26	31.89	31.52	31.15	30.77	30.40	30.03	29.66	29.29	28.92	28.55	28.18	.37079-
34.38	34	33.62	33.23	32.85	32.47	32.09	31.71	31.32	30.94	30.56	30.18	29.80	29.41	29.03	.38202+
35.39	35	34.61	34.21	33.82	33.43	33.03	32.64	32.25	31.85	31.46	31.07	30.67	30.28	29.89	.39326-
36.40	36	35.59	35.19	34.79	34.38	33.98	33.57	33.17	32.76	32.36	31.95	31.55	31.14	30.74	.40449+
37.41	37	36.58	36.17	35.75	35.34	34.92	34.50	34.09	33.67	33.26	32.84	32.43	32.01	31.59	.41573+
38.42	38	37.57	37.15	36.72	36.29	35.86	35.44	35.01	34.58	34.16	33.73	33.30	32.88	32.45	.42697-
39.44	39	38.56	38.12	37.68	37.25	36.81	36.37	35.93	35.49	35.06	34.63	34.18	33.74	33.30	.43820+
40.45	40	39.55	39.10	38.65	38.20	37.75	37.30	36.85	36.40	35.95	35.50	35.06	34.61	34.16	.44944-
41.46	41	40.54	40.08	39.62	39.16	38.70	38.23	37.77	37.31	36.85	36.39	35.93	35.47	35.01	.46067+
42.47	42	41.53	41.06	40.58	40.11	39.64	39.17	38.70	38.22	37.75	37.28	36.81	36.34	35.86	.47191-
43.48	43	42.51	42.03	41.55	41.07	40.58	40.10	39.62	39.13	38.65	38.17	37.68	37.20	36.72	.48315-
44.49	44	43.50	43.01	42.52	42.02	41.53	41.03	40.54	40.04	39.55	39.06	38.56	38.07	37.57	.49438+
45.50	45	44.49	43.99	43.48	42.98	42.47	41.97	41.46	40.95	40.45	39.94	39.44	38.93	38.43	.50562-
46.52	46	45.48	44.96	44.45	43.93	43.41	42.90	42.38	41.85	41.35	40.83	40.31	39.80	39.28	.51685+
47.53	47	46.47	45.94	45.41	44.89	44.36	43.83	43.30	42.77	42.25	41.72	41.19	40.66	40.13	.52809-
48.54	48	47.46	46.92	46.38	45.84	45.30	44.76	44.22	43.68	43.14	42.61	42.07	41.53	40.99	.53932+
49.55	49	48.45	47.90	47.35	46.80	46.25	45.70	45.14	44.59	44.04	43.49	42.94	42.39	41.84	.55056+
50.56	50	49.44	48.88	48.31	47.75	47.19	46.63	46.07	45.50	44.94	44.38	43.82	43.26	42.70	.56180-
51.57	51	50.43	49.85	49.28	48.71	48.13	47.56	46.99	46.41	45.84	45.27	44.70	44.12	43.55	.57303+
52.58	52	51.41	50.83	50.25	49.66	49.08	48.49	47.91	47.32	46.74	46.16	45.57	44.99	44.40	.58427-
53.59	53	52.40	51.81	51.21	50.62	50.02	49.43	48.83	48.23	47.64	47.04	46.45	45.85	45.26	.59550+
54.61	54	53.39	52.79	52.18	51.57	50.97	50.36	49.75	49.14	48.54	47.93	47.32	46.71	46.11	.60674+
55.62	55	54.38	53.76	53.15	52.53	51.91	51.29	50.67	50.06	49.44	48.82	48.20	47.58	46.97	.61798-
56.63	56	55.37	54.74	54.11	53.48	52.85	52.24	51.59	50.97	50.34	49.71	49.08	48.45	47.82	.62921+
57.64	57	56.36	55.72	55.08	54.44	53.80	53.16	52.52	51.88	51.24	50.59	49.95	49.31	48.67	.64045-
58.65	58	57.35	56.70	56.04	55.39	54.74	54.09	53.44	52.79	52.13	51.48	50.83	50.18	49.53	.65168+
59.66	59	58.34	57.67	57.01	56.35	55.68	55.02	54.36	53.70	53.03	52.37	51.71	51.04	50.38	.66292+
60.67	60	59.33	58.65	57.98	57.30	56.63	55.95	55.28	54.61	53.93	53.26	52.58	51.91	51.24	.67416-

TABLE III.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 11 per cent in moisture is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Cents.
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
61.68	61	60.31	59.63	58.94	58.26	57.57	56.89	56.20	55.52	54.83	54.14	53.46	52.77	52.09	0.68539+
62.70	62	61.30	60.61	59.91	59.21	58.52	57.82	57.12	56.43	55.73	55.03	54.34	53.64	52.94	.69663—
63.71	63	62.29	61.58	60.87	60.17	59.46	58.75	58.04	57.34	56.63	55.92	55.21	54.50	53.80	.70786+
64.72	64	63.28	62.56	61.84	61.12	60.40	59.68	58.97	58.25	57.53	56.82	56.11	55.37	54.65	.71910+
65.73	65	64.27	63.54	62.81	62.08	61.35	60.62	59.89	59.16	58.43	57.70	56.97	56.24	55.50	.73034—
66.74	66	65.26	64.52	63.77	63.03	62.29	61.55	60.81	60.07	59.32	58.58	57.84	57.10	56.36	.74157+
67.75	67	66.25	65.49	64.73	63.99	63.24	62.48	61.73	60.98	60.22	59.47	58.72	57.97	57.21	.75281—
68.76	68	67.23	66.47	65.71	64.94	64.18	63.41	62.65	61.89	61.12	60.36	59.59	58.83	58.07	.76404+
69.77	69	68.22	67.45	66.67	65.90	65.12	64.35	63.57	62.80	62.02	61.25	60.47	59.70	58.92	.77528—
70.79	70	69.21	68.43	67.64	66.85	66.07	65.28	64.49	63.71	62.92	62.13	61.35	60.56	59.77	.78652—
71.80	71	70.20	69.40	68.61	67.81	67.01	66.21	65.41	64.62	63.82	63.02	62.22	61.43	60.63	.79775+
72.81	72	71.19	70.38	69.57	68.76	67.95	67.15	66.34	65.53	64.72	63.91	63.10	62.29	61.48	.80899—
73.82	73	72.18	71.36	70.54	69.72	68.90	68.08	67.26	66.44	65.62	64.80	63.98	63.16	62.34	.82022+
74.83	74	73.17	72.34	71.50	70.67	69.84	69.01	68.18	67.35	66.52	65.68	64.85	64.02	63.19	.83146—
75.84	75	74.16	73.31	72.47	71.63	70.79	69.94	69.10	68.26	67.42	66.57	65.73	64.89	64.04	.84270—
76.85	76	75.14	74.29	73.44	72.58	71.73	70.88	70.02	69.17	68.31	67.46	66.61	65.75	64.90	.85393+
77.86	77	76.13	75.27	74.40	73.54	72.67	71.81	70.94	70.08	69.21	68.35	67.48	66.62	65.75	.86517—
78.88	78	77.12	76.25	75.37	74.49	73.62	72.74	71.86	70.99	70.11	69.23	68.36	67.48	66.61	.87640+
79.89	79	78.11	77.22	76.34	75.45	74.56	73.67	72.79	71.90	71.01	70.12	69.23	68.35	67.46	.88764—
80.90	80	79.10	78.20	77.30	76.40	75.51	74.61	73.71	72.81	71.91	71.01	70.11	69.21	68.31	.89888—
81.91	81	80.09	79.18	78.27	77.36	76.45	75.54	74.63	73.72	72.81	71.90	70.99	70.08	69.17	.91011+
82.92	82	81.08	80.16	79.24	78.33	77.39	76.47	75.55	74.63	73.71	72.79	71.86	70.94	70.02	.92135—
83.93	83	82.07	81.13	80.20	79.27	78.34	77.40	76.47	75.54	74.61	73.67	72.74	71.81	70.88	.93258+
84.94	84	83.06	82.11	81.17	80.22	79.28	78.34	77.39	76.45	75.50	74.56	73.62	72.67	71.73	.94382—
85.95	85	84.04	83.09	82.13	81.18	80.22	79.27	78.31	77.36	76.40	75.45	74.49	73.54	72.58	.95506—
86.97	86	85.03	84.07	83.10	82.13	81.17	80.20	79.23	78.27	77.30	76.34	75.37	74.40	73.44	.96629+
87.98	87	86.02	85.04	84.07	83.09	82.11	81.13	80.16	79.18	78.20	77.22	76.25	75.27	74.29	.97753—
88.99	88	87.01	86.02	85.03	84.04	83.05	82.07	81.08	80.09	79.10	78.11	77.12	76.13	75.14	.98876+
90.00	89	88.00	87.00	86.00	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000
91.01	90	88.99	87.98	86.96	85.95	84.93	83.93	82.92	81.91	80.90	79.89	78.87	77.86	76.85	1.0123+
92.02	91	89.98	88.95	87.93	86.91	85.89	84.86	83.84	82.82	81.80	80.77	79.75	78.73	77.71	1.02247+
93.03	92	90.97	89.93	88.90	87.86	86.83	85.80	84.76	83.73	82.70	81.66	80.63	79.59	78.56	1.03371—
94.04	93	91.95	90.91	89.86	88.82	87.77	86.73	85.68	84.64	83.59	82.55	81.50	80.46	79.41	1.04494+
95.06	94	92.94	91.89	90.83	89.77	88.72	87.66	86.61	85.55	84.49	83.44	82.38	81.32	80.27	1.05618+
96.07	95	93.93	92.86	91.80	90.73	89.66	88.59	87.53	86.46	85.39	84.32	83.26	82.19	81.12	1.06741+
97.08	96	94.92	93.84	92.76	91.68	90.61	89.53	88.45	87.37	86.29	85.21	84.13	83.06	81.98	1.07865+
98.09	97	95.91	94.82	93.73	92.64	91.55	90.46	89.37	88.28	87.19	86.10	85.01	83.92	82.83	1.08989—
99.10	98	96.90	95.80	94.70	93.59	92.49	91.39	90.29	89.19	88.09	86.99	85.89	84.79	83.68	1.10112+
100.11	99	97.89	96.77	95.66	94.55	93.43	92.32	91.21	90.10	88.99	87.88	86.76	85.65	84.54	1.11236—
101.12	100	98.87	97.75	96.63	95.50	94.38	93.26	92.13	91.01	89.89	88.79	87.64	86.52	85.39	1.12359+
102.13	101	99.86	98.73	97.59	96.46	95.32	94.19	93.06	91.92	90.79	89.65	88.52	87.38	86.25	1.13483+
103.15	102	100.85	99.71	98.56	97.41	96.27	95.12	93.98	92.83	91.68	90.54	89.39	88.25	87.10	1.14607—
104.16	103	101.84	100.68	99.53	98.37	97.21	96.05	94.90	93.74	92.58	91.43	90.27	89.11	87.95	1.15730+
105.17	104	102.83	101.66	100.49	99.32	98.16	96.99	95.82	94.65	93.48	92.31	91.15	89.98	88.81	1.16854+
106.18	105	103.82	102.64	101.46	100.28	99.10	97.92	96.74	95.56	94.38	93.20	92.02	90.84	89.66	1.17977+
107.19	106	104.81	103.63	102.43	101.23	100.04	98.85	97.66	96.47	95.28	94.09	92.90	91.71	90.52	1.19101+
108.20	107	105.80	104.59	103.39	102.19	100.99	99.79	98.58	97.38	96.18	94.98	93.77	92.57	91.37	1.20225—
109.21	108	106.79	105.57	104.35	103.14	101.93	100.72	99.50	98.29	97.08	95.86	94.65	93.44	92.22	1.21348+
110.22	109	107.77	106.55	105.33	104.10	102.88	101.65	100.43	99.20	97.98	96.75	95.53	94.30	93.08	1.22472—
111.23	110	108.76	107.53	106.29	105.05	103.83	102.58	101.35	100.11	98.88	97.64	96.40	95.17	93.93	1.23595+
112.25	111	109.75	108.50	107.26	106.01	104.76	103.52	102.27	101.02	99.77	98.53	97.28	96.03	94.79	1.24719+
113.26	112	110.74	109.48	108.22	106.97	105.71	104.45	103.19	101.93	100.67	99.41	98.16	96.90	95.64	1.25843—
114.27	113	111.73	110.46	109.19	107.92	106.65	105.38	104.11	102.84	101.57	100.31	99.03	97.76	96.49	1.26966+
115.28	114	112.72	111.44	110.16	108.88	107.59	106.31	105.03	103.75	102.47	101.19	99.91	98.63	97.35	1.28090—
116.29	115	113.71	112.41	111.12	109.83	108.54	107.25	105.95	104.66	103.37	102.08	100.79	99.49	98.20	1.29213+
117.30	116	114.70	113.39	112.09	110.79	109.48	108.18	106.88	105.57	104.27	102.97	101.66	100.36	99.06	1.30337
118.31	117	115.68	114.37	113.06	111.74	110.43	109.11	107.80	106.48	105.17	103.85	102.54	101.22	99.91	1.31461—
119.32	118	116.67	115.34	114.02	112.70	111.37	110.04	108.72	107.39	106.07	104.74	103.41	102.09	100.76	1.32584+
120.34	119	117.66	116.32	114.99	113.65	112.31	110.98	109.64	108.30	106.97	105.63	104.29	102.95	101.62	1.33708—
121.35	120	118.65	117.30	115.95	114.61	113.26	111.91	110.56	109.21	107.86	106.52	105.17	103.82	102.47	1.34831+

TABLE IV.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 12 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.																Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.	
1.02	1.01	1	0.99	0.98	0.96	0.95	0.94	0.93	0.92	0.91	0.90	0.89	0.87	0.86	0.01136+	
2.04	2.02	2	1.98	1.95	1.93	1.91	1.89	1.86	1.84	1.82	1.79	1.77	1.75	1.73	0.02273-	
3.07	3.03	3	2.96	2.93	2.90	2.86	2.83	2.79	2.76	2.73	2.69	2.66	2.62	2.59	0.03409	
4.09	4.04	4	3.95	3.91	3.86	3.82	3.77	3.73	3.68	3.64	3.59	3.54	3.50	3.45	0.04545+	
5.11	5.06	5	4.94	4.89	4.83	4.77	4.72	4.66	4.60	4.54	4.49	4.43	4.37	4.32	0.05682-	
6.14	6.07	6	5.93	5.86	5.79	5.73	5.66	5.59	5.52	5.45	5.39	5.32	5.25	5.18	0.06818+	
7.16	7.08	7	6.92	6.84	6.76	6.68	6.60	6.52	6.44	6.36	6.28	6.20	6.12	6.04	0.07954+	
8.18	8.09	8	7.91	7.82	7.73	7.64	7.54	7.45	7.36	7.27	7.18	7.09	7.00	6.91	0.09091-	
9.20	9.10	9	8.90	8.79	8.69	8.59	8.49	8.39	8.28	8.18	8.08	7.98	7.87	7.77	0.10227+	
10.23	10.11	10	9.89	9.77	9.66	9.54	9.43	9.32	9.20	9.09	8.98	8.86	8.75	8.64	0.11364-	
11.25	11.12	11	10.87	10.75	10.62	10.50	10.37	10.25	10.12	10.00	9.87	9.75	9.62	9.50	0.12500-	
12.27	12.14	12	11.88	11.73	11.59	11.45	11.32	11.18	11.04	10.91	10.77	10.64	10.50	10.36	0.13636+	
13.29	13.15	13	12.85	12.70	12.56	12.41	12.26	12.11	11.97	11.82	11.67	11.52	11.37	11.23	0.14773-	
14.32	14.16	14	13.84	13.68	13.52	13.36	13.20	13.04	12.89	12.73	12.57	12.41	12.25	12.09	0.15909-	
15.34	15.17	15	14.83	14.66	14.49	14.32	14.15	13.98	13.81	13.64	13.46	13.29	13.12	12.95	0.17045+	
16.36	16.18	16	15.82	15.64	15.45	15.27	15.09	14.91	14.73	14.54	14.36	14.18	14.00	13.82	0.18182-	
17.39	17.19	17	16.81	16.61	16.42	16.23	16.03	15.84	15.65	15.45	15.25	15.07	14.87	14.68	0.19318+	
18.41	18.20	18	17.79	17.59	17.38	17.18	16.98	16.77	16.57	16.36	16.16	15.95	15.75	15.54	0.20454+	
19.43	19.21	19	18.78	18.57	18.35	18.14	17.92	17.70	17.49	17.27	17.06	16.84	16.62	16.41	0.21591-	
20.45	20.23	20	19.77	19.54	19.32	19.09	18.86	18.64	18.41	18.18	17.95	17.73	17.50	17.27	0.22727+	
21.48	21.24	21	20.76	20.52	20.28	20.04	19.81	19.57	19.33	19.09	18.85	18.61	18.37	18.14	0.23864-	
22.50	22.25	22	21.75	21.50	21.25	21.00	20.75	20.50	20.25	20.00	19.75	19.50	19.25	19.00	0.25000	
23.52	23.26	23	22.74	22.48	22.21	21.95	21.69	21.43	21.17	20.91	20.65	20.39	20.12	19.86	0.26136+	
24.54	24.27	24	23.73	23.45	23.18	22.91	22.64	22.36	22.09	21.82	21.54	21.27	21.00	20.73	0.27273+	
25.57	25.28	25	24.71	24.43	24.15	23.86	23.58	23.29	23.01	22.73	22.44	22.16	21.87	21.59	0.28409	
26.59	26.29	26	25.70	25.41	25.11	24.82	24.52	24.23	23.93	23.64	23.34	23.04	22.75	22.45	0.29545+	
27.61	27.31	27	26.69	26.39	26.08	25.77	25.47	25.16	24.85	24.54	24.24	23.93	23.62	23.32	0.30682-	
28.64	28.32	28	27.68	27.36	27.04	26.73	26.41	26.09	25.77	25.45	25.14	24.82	24.50	24.18	0.31818+	
29.66	29.33	29	28.67	28.34	28.01	27.68	27.35	27.02	26.69	26.36	26.03	25.70	25.37	25.04	0.32954+	
30.68	30.34	30	29.66	29.32	28.98	28.64	28.29	27.95	27.61	27.27	26.93	26.59	26.25	25.91	0.34091-	
31.70	31.35	31	30.65	30.29	29.91	29.59	29.24	28.89	28.53	28.18	27.83	27.48	27.12	26.77	0.35227+	
32.73	32.36	32	31.64	31.27	30.91	30.54	30.18	29.82	29.45	29.09	28.73	28.36	28.00	27.64	0.36364-	
33.75	33.37	33	32.62	32.25	31.87	31.50	31.12	30.75	30.37	30.00	29.62	29.25	28.87	28.50	0.37500	
34.77	34.39	34	33.61	33.23	32.84	32.45	32.07	31.68	31.29	30.91	30.52	30.14	29.75	29.36	0.38636+	
35.79	35.40	35	34.60	34.20	33.81	33.41	33.01	32.61	32.21	31.82	31.42	31.02	30.62	30.23	0.39773-	
36.82	36.41	36	35.59	35.18	34.77	34.36	33.95	33.54	33.14	32.73	32.32	31.91	31.50	31.09	0.40909	
37.84	37.42	37	36.58	36.16	35.74	35.32	34.91	34.48	34.06	33.64	33.21	32.79	32.37	31.95	0.42045+	
38.86	38.43	38	37.57	37.14	36.70	36.27	35.84	35.41	34.98	34.54	34.11	33.68	33.25	32.82	0.43182-	
39.89	39.44	39	38.56	38.11	37.67	37.23	36.78	36.34	35.90	35.45	35.01	34.57	34.12	33.68	0.44318+	
40.91	40.45	40	39.54	39.09	38.63	38.18	37.73	37.27	36.82	36.36	35.91	35.45	35.00	34.54	0.45454+	
41.93	41.46	41	40.53	40.07	39.60	39.14	38.67	38.20	37.74	37.27	36.81	36.34	35.87	35.41	0.46591-	
42.95	42.48	42	41.52	41.04	40.57	40.09	39.61	39.14	38.66	38.18	37.70	37.23	36.75	36.27	0.47727+	
43.98	43.49	43	42.51	42.02	41.53	41.04	40.56	40.07	39.58	39.09	38.60	38.11	37.62	37.14	0.48864-	
45.00	44.50	44	43.50	43.00	42.50	42.00	41.50	41.00	40.50	40.00	39.50	39.00	38.50	38.00	0.50000	
46.02	45.51	45	44.49	43.98	43.46	42.95	42.44	41.93	41.42	40.91	40.40	39.89	39.37	38.86	0.51136+	
47.04	46.52	46	45.48	44.95	44.43	43.91	43.39	42.86	42.34	41.82	41.29	40.77	40.25	39.73	0.52273-	
48.07	47.53	47	46.46	45.93	45.40	44.86	44.33	43.79	43.26	42.73	42.19	41.66	41.12	40.59	0.53409	
49.09	48.54	48	47.45	46.91	46.36	45.82	45.27	44.73	44.18	43.64	43.09	42.54	42.00	41.45	0.54545+	
50.11	49.56	49	48.44	47.89	47.33	46.77	46.22	45.66	45.10	44.54	43.99	43.43	42.87	42.32	0.55682-	
51.14	50.57	50	49.43	48.86	48.29	47.73	47.16	46.59	46.02	45.45	44.89	44.32	43.75	43.18	0.56818+	
52.16	51.58	51	50.42	49.84	49.26	48.68	48.10	47.52	46.94	46.36	45.78	45.20	44.62	44.04	0.57954+	
53.18	52.59	52	51.41	50.82	50.23	49.64	49.04	48.45	47.86	47.27	46.68	46.09	45.50	44.91	0.59091-	
54.20	53.60	53	52.40	51.79	51.19	50.59	49.99	49.39	48.78	48.18	47.58	46.98	46.37	45.77	0.60227+	
55.23	54.61	54	53.39	52.77	52.16	51.55	50.93	50.32	49.70	49.09	48.48	47.86	47.25	46.64	0.61364-	
56.25	55.62	55	54.37	53.75	53.12	52.50	51.87	51.25	50.62	50.00	49.37	48.75	48.12	47.50	0.62500+	
57.27	56.64	56	55.36	54.73	54.09	53.45	52.82	52.18	51.54	50.91	50.27	49.64	49.00	48.36	0.63636+	
58.29	57.65	57	56.35	55.70	55.06	54.41	53.76	53.11	52.47	51.82	51.17	50.52	49.87	49.23	0.64773-	
59.32	58.66	58	57.34	56.68	56.02	55.36	54.70	54.04	53.39	52.73	52.07	51.41	50.75	50.09	0.65909	
60.34	59.67	59	58.33	57.66	56.99	56.32	55.65	54.98	54.31	53.64	52.96	52.29	51.62	50.95	0.67045+	
61.36	60.68	60	59.32	58.64	57.95	57.27	56.59	55.91	55.23	54.54	53.86	53.18	52.50	51.82	0.68182-	

TABLE IV.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 12 per cent in moisture is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
62.39	61.69	61	60.31	59.61	58.92	58.23	57.53	56.84	56.15	55.45	54.76	54.07	53.37	52.68	0.69318+
63.41	62.70	62	61.29	60.59	59.88	59.18	58.48	57.77	57.07	56.36	55.66	54.95	54.25	53.54	.70454+
64.43	63.71	63	62.28	61.57	60.85	60.14	59.42	58.70	57.99	57.27	56.56	55.84	55.12	54.41	.71591+
65.45	64.73	64	63.27	62.54	61.82	61.09	60.36	59.64	58.91	58.18	57.45	56.73	56.00	55.27	.72727+
66.48	65.74	65	64.26	63.52	62.78	62.04	61.31	60.57	59.83	59.09	58.35	57.61	56.87	56.14	.73864+
67.50	66.75	66	65.25	64.50	63.75	63.00	62.25	61.50	60.75	60.00	59.25	58.50	57.75	57.00	.75000
68.52	67.76	67	66.24	65.48	64.71	63.95	63.19	62.43	61.67	60.91	60.15	59.39	58.62	57.86	.76136+
69.54	68.77	68	67.23	66.45	65.68	64.91	64.14	63.36	62.59	61.82	61.04	60.27	59.50	58.73	.77273+
70.57	69.78	69	68.21	67.43	66.65	65.86	65.08	64.29	63.51	62.73	61.94	61.16	60.37	59.59	.78409
71.59	70.79	70	69.20	68.41	67.61	66.82	66.02	65.23	64.43	63.64	62.84	62.04	61.25	60.45	.79545+
72.61	71.81	71	70.19	69.39	68.58	67.77	66.97	66.16	65.35	64.54	63.74	62.93	62.12	61.32	.80682+
73.64	72.82	72	71.18	70.36	69.54	68.73	67.91	67.09	66.27	65.45	64.64	63.82	63.00	62.18	.81818+
74.66	73.83	73	72.17	71.34	70.51	69.68	68.85	68.02	67.19	66.36	65.53	64.70	63.87	63.04	.82954+
75.68	74.84	74	73.16	72.32	71.48	70.64	69.79	68.95	68.11	67.27	66.43	65.59	64.75	63.91	.84091+
76.70	75.85	75	74.15	73.29	72.44	71.59	70.74	69.89	69.03	68.18	67.33	66.48	65.62	64.77	.85227+
77.73	76.86	76	75.14	74.27	73.41	72.54	71.68	70.82	69.95	69.09	68.23	67.36	66.50	65.64	.86364+
78.75	77.87	77	76.12	75.25	74.37	73.50	72.62	71.75	70.87	70.00	69.12	68.25	67.37	66.50	.87500
79.77	78.89	78	77.11	76.23	75.34	74.45	73.57	72.68	71.79	70.91	70.02	69.14	68.25	67.36	.88636+
80.79	79.90	79	78.10	77.20	76.31	75.41	74.51	73.61	72.72	71.82	70.92	70.02	69.12	68.23	.89773+
81.82	80.91	80	79.09	78.18	77.27	76.36	75.45	74.54	73.64	72.73	71.82	70.91	70.00	69.09	.90909
82.84	81.92	81	80.08	79.16	78.24	77.32	76.40	75.48	74.56	73.64	72.71	71.79	70.87	69.95	.92045+
83.86	82.93	82	81.07	80.14	79.20	78.27	77.34	76.41	75.48	74.54	73.61	72.68	71.75	70.82	.93182+
84.89	83.94	83	82.06	81.11	80.17	79.23	78.28	77.34	76.40	75.45	74.51	73.57	72.62	71.68	.94318+
85.91	84.95	84	83.04	82.09	81.13	80.18	79.23	78.27	77.32	76.36	75.41	74.45	73.50	72.54	.95454+
86.93	85.96	85	84.03	83.07	82.10	81.14	80.17	79.20	78.24	77.27	76.31	75.34	74.37	73.41	.96591+
87.95	86.98	86	85.02	84.04	83.07	82.09	81.11	80.14	79.16	78.18	77.20	76.23	75.25	74.27	.97727+
88.98	87.99	87	86.01	85.02	84.03	83.04	82.06	81.07	80.08	79.09	78.10	77.11	76.12	75.14	.98864+
90.00	89.00	88	87.00	86.00	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000
91.02	90.01	89	87.99	86.98	85.96	84.95	83.94	82.93	81.92	80.91	79.90	78.89	77.87	76.86	1.01136+
92.04	91.02	90	88.98	87.95	86.93	85.91	84.89	83.86	82.84	81.82	80.79	79.77	78.75	77.73	1.02273+
93.07	92.03	91	89.96	88.93	87.90	86.86	85.83	84.79	83.76	82.73	81.69	80.66	79.62	78.59	1.03409
94.09	93.04	92	90.95	89.91	88.86	87.82	86.77	85.73	84.68	83.64	82.59	81.54	80.50	79.45	1.04545+
95.11	94.06	93	91.94	90.89	89.83	88.77	87.72	86.66	85.60	84.54	83.49	82.43	81.37	80.32	1.05682+
96.14	95.07	94	92.93	91.86	90.79	89.73	88.66	87.59	86.52	85.45	84.39	83.32	82.25	81.18	1.06818+
97.16	96.08	95	93.92	92.84	91.76	90.68	89.60	88.52	87.44	86.36	85.28	84.20	83.12	82.04	1.07954+
98.18	97.09	96	94.91	93.82	92.73	91.64	90.54	89.45	88.36	87.27	86.18	85.09	84.00	82.91	1.09091+
99.20	98.10	97	95.90	94.79	93.69	92.59	91.49	90.39	89.28	88.18	87.08	85.98	84.87	83.77	1.10227+
100.23	99.11	98	96.89	95.77	94.66	93.54	92.43	91.32	90.20	89.09	87.98	86.86	85.75	84.64	1.11364+
101.25	100.12	99	97.87	96.75	95.62	94.50	93.37	92.25	91.12	90.00	88.87	87.75	86.62	85.50	1.12500
102.27	101.14	100	98.86	97.73	96.59	95.45	94.32	93.18	92.04	90.91	89.77	88.64	87.50	86.36	1.13636+
103.29	102.15	101	99.85	98.70	97.56	96.41	95.26	94.11	92.97	91.82	90.67	89.52	88.37	87.22	1.14773+
104.32	103.16	102	100.84	99.68	98.52	97.36	96.20	95.04	93.89	92.73	91.57	90.41	89.25	88.09	1.15909
105.34	104.17	103	101.83	100.66	99.49	98.32	97.15	95.98	94.81	93.64	92.46	91.29	90.12	88.95	1.17045+
106.36	105.18	104	102.82	101.64	100.45	99.27	98.09	96.91	95.73	94.54	93.36	92.18	91.00	89.82	1.18182+
107.39	106.19	105	103.81	102.61	101.42	100.23	99.03	97.84	96.65	95.45	94.26	93.07	91.87	90.68	1.19318+
108.41	107.20	106	104.79	103.59	102.38	101.18	99.98	98.77	97.57	96.36	95.16	93.95	92.75	91.54	1.20454+
109.43	108.21	107	105.78	104.57	103.35	102.14	100.92	99.70	98.49	97.27	96.06	94.84	93.62	92.41	1.21591+
110.45	109.23	108	106.77	105.54	104.32	103.09	101.86	100.64	99.41	98.18	96.95	95.73	94.50	93.27	1.22727+
111.48	110.24	109	107.76	106.52	105.28	104.04	102.81	101.57	100.33	99.09	97.85	96.61	95.37	94.14	1.23864+
112.50	111.25	110	108.75	107.50	106.25	105.00	103.75	102.50	101.25	100.00	98.75	97.50	96.25	95.00	1.25000
113.52	112.26	111	109.74	108.48	107.21	105.95	104.69	103.43	102.17	100.91	99.65	98.39	97.12	95.86	1.26136+
114.54	113.27	112	110.73	109.45	108.18	106.91	105.64	104.36	103.09	101.82	100.54	99.27	98.00	96.73	1.27273+
115.57	114.28	113	111.71	110.43	109.15	107.86	106.58	105.29	104.01	102.73	101.44	100.16	98.87	97.59	1.28409
116.59	115.29	114	112.70	111.41	110.11	108.82	107.52	106.23	104.93	103.64	102.34	101.04	99.75	98.45	1.29545+
117.61	116.31	115	113.69	112.39	111.08	109.77	108.47	107.16	105.85	104.54	103.24	101.93	100.62	99.32	1.30682+
118.64	117.32	116	114.68	113.36	112.04	110.73	109.41	108.09	106.77	105.45	104.14	102.82	101.50	100.18	1.31818+
119.66	118.33	117	115.67	114.34	113.01	111.68	110.35	109.02	107.69	106.36	105.03	103.70	102.37	101.04	1.32954+
120.68	119.34	118	116.66	115.32	113.98	112.64	111.29	109.95	108.61	107.27	105.93	104.59	103.25	101.91	1.34091+
121.70	120.35	119	117.65	116.29	114.94	113.59	112.24	110.89	109.53	108.18	106.83	105.48	104.12	102.77	1.35227+
122.73	121.36	120	118.64	117.27	115.91	114.54	113.18	111.82	110.45	109.09	107.73	106.36	105.00	103.64	1.36364+

TABLE V.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 13 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
1.03	1.02	1.01	1	0.99	0.98	0.95	0.95	0.94	0.93	0.92	0.91	0.90	0.88	0.87	0.01149+
2.07	2.05	2.02	2	1.98	1.95	1.93	1.91	1.88	1.86	1.84	1.82	1.79	1.77	1.75	.02299—
3.10	3.07	3.03	3	2.96	2.93	2.90	2.86	2.83	2.79	2.76	2.72	2.69	2.65	2.62	.03448+
4.14	4.09	4.05	4	3.95	3.91	3.86	3.82	3.77	3.72	3.68	3.63	3.59	3.54	3.49	.04598—
5.17	5.11	5.06	5	4.94	4.88	4.83	4.77	4.71	4.65	4.60	4.54	4.48	4.42	4.37	.05747+
6.21	6.14	6.07	6	5.93	5.86	5.79	5.72	5.65	5.58	5.52	5.45	5.38	5.31	5.24	.06896+
7.24	7.16	7.08	7	6.92	6.84	6.76	6.68	6.60	6.52	6.44	6.36	6.27	6.19	6.11	.08046—
8.27	8.18	8.09	8	7.91	7.81	7.72	7.63	7.54	7.45	7.36	7.26	7.17	7.08	6.99	.09195+
9.31	9.21	9.10	9	8.90	8.79	8.69	8.59	8.48	8.38	8.28	8.17	8.07	7.96	7.86	.10345—
10.34	10.23	10.11	10	9.88	9.77	9.65	9.54	9.42	9.31	9.19	9.08	8.96	8.85	8.73	.11494+
11.38	11.25	11.13	11	10.87	10.75	10.62	10.49	10.37	10.24	10.11	9.99	9.86	9.73	9.61	.12644—
12.41	12.27	12.14	12	11.86	11.72	11.59	11.45	11.31	11.17	11.03	10.89	10.76	10.62	10.48	.13793+
13.45	13.30	13.15	13	12.85	12.70	12.55	12.40	12.25	12.10	11.95	11.80	11.65	11.50	11.35	.14942+
14.48	14.32	14.16	14	13.84	13.68	13.52	13.36	13.19	13.03	12.87	12.71	12.55	12.39	12.23	.16092—
15.52	15.34	15.17	15	14.83	14.65	14.48	14.31	14.14	13.96	13.79	13.62	13.45	13.27	13.10	.17241+
16.55	16.37	16.18	16	15.82	15.63	15.45	15.26	15.08	14.90	14.71	14.53	14.34	14.16	13.98	.18391—
17.59	17.39	17.19	17	16.80	16.61	16.41	16.22	16.02	15.83	15.63	15.44	15.24	15.04	14.85	.19540+
18.62	18.41	18.21	18	17.79	17.59	17.38	17.17	16.96	16.76	16.55	16.34	16.14	15.93	15.72	.20690—
19.65	19.44	19.22	19	18.78	18.56	18.34	18.13	17.91	17.69	17.47	17.25	17.03	16.82	16.60	.21839+
20.69	20.46	20.23	20	19.77	19.54	19.31	19.08	18.85	18.62	18.39	18.16	17.93	17.70	17.47	.22988+
21.72	21.48	21.24	21	20.76	20.52	20.27	20.03	19.79	19.55	19.31	19.07	18.83	18.59	18.34	.24138—
22.76	22.50	22.25	22	21.75	21.49	21.24	20.99	20.73	20.48	20.23	19.98	19.72	19.47	19.22	.25287+
23.79	23.53	23.26	23	22.73	22.47	22.21	21.94	21.68	21.41	21.15	20.88	20.62	20.36	20.09	.26437—
24.83	24.55	24.27	24	23.72	23.45	23.17	22.90	22.62	22.34	22.07	21.79	21.52	21.24	20.96	.27586+
25.86	25.57	25.29	25	24.71	24.42	24.14	23.85	23.56	23.28	22.99	22.70	22.41	22.12	21.83	.28736—
26.90	26.60	26.30	26	25.70	25.40	25.10	24.80	24.50	24.21	23.91	23.61	23.31	23.01	22.71	.29885
27.93	27.62	27.31	27	26.69	26.38	26.07	25.76	25.45	25.14	24.83	24.52	24.21	23.90	23.58	.31034+
28.96	28.64	28.32	28	27.68	27.36	27.03	26.71	26.39	26.07	25.75	25.42	25.10	24.78	24.46	.32184—
30.00	29.67	29.33	29	28.67	28.33	28.00	27.67	27.33	27.00	26.67	26.33	26.00	25.67	25.33	.33333+
31.03	30.69	30.34	30	29.65	29.31	28.96	28.62	28.28	27.93	27.59	27.24	26.90	26.55	26.21	.34483—
32.07	31.71	31.36	31	30.64	30.29	29.93	29.57	29.22	28.86	28.50	28.15	27.79	27.44	27.08	.35632+
33.10	32.73	32.37	32	31.63	31.26	30.90	30.53	30.16	29.79	29.42	29.06	28.69	28.32	27.95	.36782—
34.14	33.76	33.38	33	32.62	32.24	31.86	31.48	31.10	30.72	30.34	29.96	29.59	29.21	28.83	.37931
35.17	34.78	34.39	34	33.61	33.22	32.83	32.44	32.04	31.65	31.26	30.87	30.48	30.09	29.70	.39080+
36.21	35.80	35.40	35	34.60	34.19	33.79	33.39	32.99	32.59	32.18	31.78	31.38	30.98	30.57	.40230—
37.24	36.83	36.41	36	35.58	35.17	34.76	34.34	33.93	33.52	33.10	32.69	32.27	31.86	31.45	.41379+
38.28	37.85	37.42	37	36.57	36.15	35.72	35.30	34.87	34.45	34.02	33.60	33.17	32.75	32.32	.42529—
39.31	38.87	38.44	38	37.55	37.13	36.69	36.25	35.81	35.38	34.94	34.50	34.07	33.63	33.19	.43678+
40.34	39.90	39.45	39	38.55	38.10	37.65	37.21	36.76	36.31	35.86	35.41	34.96	34.52	34.07	.44827+
41.38	40.92	40.46	40	39.54	39.08	38.62	38.16	37.70	37.24	36.78	36.32	35.86	35.40	34.94	.45977—
42.41	41.94	41.47	41	40.53	40.06	39.58	39.11	38.64	38.17	37.70	37.23	36.76	36.29	35.81	.47126+
43.45	42.96	42.48	42	41.52	41.03	40.55	40.07	39.59	39.10	38.62	38.14	37.65	37.17	36.69	.48276—
44.48	43.99	43.49	43	42.50	42.01	41.52	41.02	40.53	40.03	39.54	39.04	38.55	38.06	37.56	.49425+
45.52	45.01	44.51	44	43.49	42.99	42.48	41.98	41.47	40.96	40.46	39.95	39.45	38.94	38.44	.50575—
46.55	46.03	45.52	45	44.48	43.96	43.45	42.93	42.41	41.90	41.38	40.86	40.34	39.83	39.31	.51724+
47.58	47.06	46.53	46	45.47	44.94	44.41	43.88	43.35	42.83	42.30	41.77	41.24	40.71	40.18	.52873+
48.62	48.08	47.54	47	46.45	45.92	45.38	44.84	44.30	43.76	43.22	42.68	42.14	41.60	41.06	.54023—
49.65	49.10	48.55	48	47.43	46.90	46.34	45.79	45.24	44.69	44.14	43.58	43.03	42.48	41.93	.55172+
50.69	50.13	49.56	49	48.44	47.87	47.31	46.75	46.18	45.62	45.06	44.49	43.93	43.37	42.80	.56322—
51.72	51.15	50.57	50	49.42	48.85	48.27	47.70	47.13	46.55	45.98	45.40	44.83	44.25	43.68	.57471+
52.76	52.17	51.59	51	50.41	49.83	49.24	48.65	48.07	47.48	46.90	46.31	45.72	45.14	44.55	.58621—
53.79	53.19	52.60	52	51.40	50.80	50.21	49.61	49.01	48.41	47.82	47.22	46.62	46.02	45.42	.59770+
54.83	54.22	53.61	53	52.39	51.78	51.17	50.56	49.95	49.34	48.73	48.13	47.52	46.91	46.30	.60919+
55.86	55.24	54.62	54	53.38	52.76	52.14	51.52	50.90	50.27	49.65	49.03	48.41	47.79	47.17	.62069—
56.90	56.26	55.63	55	54.37	53.73	53.10	52.47	51.84	51.21	50.57	49.94	49.31	48.68	48.04	.63218+
57.93	57.29	56.64	56	55.36	54.71	54.07	53.42	52.78	52.14	51.49	50.85	50.21	49.56	48.92	.64368—
58.96	58.31	57.65	57	56.34	55.69	55.03	54.38	53.72	53.07	52.41	51.76	51.10	50.45	49.79	.65517+
60.00	59.33	58.67	58	57.33	56.67	56.00	55.33	54.67	54.00	53.33	52.67	52.00	51.33	50.67	.66667—
61.03	60.36	59.68	59	58.32	57.64	56.96	56.29	55.61	54.93	54.25	53.57	52.90	52.22	51.54	.67816
62.07	61.38	60.69	60	59.31	58.62	57.93	57.24	56.55	55.86	55.17	54.48	53.79	53.10	52.41	.68965+

TABLE V.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 13 per cent in moisture is in even cents.—Continued.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
63.10	62.40	61.70	61	60.30	59.60	58.90	58.19	57.49	56.79	56.09	55.39	54.69	53.99	53.29	0.70115—
64.14	63.42	62.71	62	61.29	60.57	59.85	59.15	58.44	57.72	57.01	56.30	55.58	54.87	54.16	.71264+
65.17	64.45	63.72	63	62.28	61.55	60.83	60.10	59.38	58.65	57.93	57.21	56.48	55.76	55.03	.72414+
66.21	65.47	64.73	64	63.25	62.53	61.79	61.06	60.32	59.59	58.85	58.11	57.38	56.64	55.91	.73563+
67.24	66.49	65.75	65	64.25	63.51	62.76	62.01	61.26	60.52	59.77	59.02	58.28	57.53	56.78	.74713—
68.27	67.52	66.76	66	65.24	64.48	63.72	62.96	62.21	61.45	60.69	59.93	59.17	58.41	57.65	.75862
69.31	68.54	67.77	67	66.23	65.46	64.69	63.92	63.15	62.38	61.61	60.84	60.07	59.30	58.53	.77011+
70.34	69.56	68.78	68	67.22	66.44	65.65	64.87	64.09	63.31	62.53	61.75	60.96	60.18	59.40	.78161—
71.38	70.58	69.79	69	68.21	67.41	66.62	65.83	65.03	64.24	63.45	62.65	61.86	61.07	60.27	.79310+
72.41	71.61	70.80	70	69.19	68.39	67.59	66.78	65.98	65.17	64.37	63.56	62.76	61.95	61.15	.80460—
73.45	72.63	71.81	71	70.18	69.37	68.55	67.73	66.92	66.10	65.29	64.47	63.65	62.84	62.02	.81609+
74.48	73.65	72.83	72	71.17	70.34	69.52	68.69	67.86	67.03	66.21	65.38	64.55	63.72	62.90	.82759+
75.52	74.68	73.84	73	72.16	71.32	70.48	69.64	68.80	67.96	67.13	66.29	65.45	64.61	63.77	.83908
76.55	75.70	74.85	74	73.15	72.30	71.45	70.60	69.75	68.90	68.04	67.19	66.34	65.49	64.64	.85057+
77.59	76.72	75.85	75	74.14	73.27	72.41	71.55	70.69	69.83	68.96	68.10	67.24	66.38	65.52	.86207—
78.62	77.75	76.87	76	75.13	74.25	73.38	72.50	71.63	70.76	69.88	69.01	68.14	67.26	66.39	.87356+
79.65	78.77	77.88	77	76.11	75.23	74.34	73.46	72.57	71.69	70.80	69.92	69.03	68.15	67.26	.88503—
80.69	79.79	78.90	78	77.10	76.21	75.31	74.41	73.52	72.62	71.72	70.83	69.93	69.03	68.14	.89653+
81.72	80.81	79.91	79	78.09	77.18	76.27	75.37	74.46	73.55	72.64	71.73	70.83	69.92	69.01	.90804+
82.76	81.84	80.92	80	79.08	78.15	77.24	76.32	75.40	74.48	73.56	72.64	71.72	70.80	69.88	.91954—
83.79	82.86	81.93	81	80.07	79.14	78.21	77.27	76.34	75.41	74.48	73.55	72.62	71.69	70.76	.93103+
84.83	83.88	82.94	82	81.06	80.11	79.17	78.23	77.29	76.34	75.40	74.46	73.52	72.57	71.63	.94253—
85.86	84.91	83.95	83	82.04	81.09	80.14	79.18	78.23	77.27	76.32	75.37	74.41	73.46	72.50	.95402+
86.90	85.93	84.93	84	83.03	82.07	81.10	80.14	79.17	78.21	77.24	76.28	75.31	74.34	73.38	.96552+
87.93	86.95	85.95	85	84.02	83.04	82.07	81.09	80.11	79.14	78.16	77.18	76.21	75.23	74.25	.97701—
88.96	87.98	86.99	86	85.01	84.02	83.03	82.04	81.06	80.07	79.08	78.09	77.10	76.11	75.13	.98850+
89.99	89.00	88.00	87	86.00	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000
91.03	90.02	89.01	88	86.99	85.98	84.96	83.95	82.94	81.93	80.92	79.91	78.90	77.88	76.87	1.01149+
92.07	91.05	90.02	89	87.98	86.95	85.93	84.91	83.89	82.86	81.84	80.82	79.79	78.77	77.75	1.02300+
93.10	92.07	91.03	90	88.96	87.93	86.90	85.86	84.83	83.79	82.76	81.72	80.69	79.65	78.62	1.03448+
94.14	93.09	92.05	91	89.96	88.91	87.86	86.82	85.77	84.73	83.68	82.63	81.59	80.54	79.50	1.04600—
95.17	94.11	93.03	92	90.94	89.88	88.83	87.77	86.71	85.65	84.60	83.54	82.48	81.42	80.37	1.05747+
96.21	95.14	94.07	93	91.93	90.86	89.80	88.73	87.66	86.59	85.52	84.45	83.38	82.31	81.24	1.06890+
97.24	96.16	95.08	94	92.92	91.84	90.76	89.68	88.60	87.52	86.44	85.36	84.27	83.19	82.11	1.08048—
98.27	97.18	96.09	95	93.91	92.81	91.72	90.63	89.54	88.45	87.36	86.26	85.17	84.08	82.99	1.09195+
99.31	98.21	97.10	96	94.90	93.79	92.69	91.59	90.48	89.38	88.28	87.17	86.07	84.96	83.86	1.10345—
100.34	99.23	98.11	97	95.88	94.77	93.65	92.54	91.42	90.31	89.19	88.08	86.96	85.85	84.73	1.11494+
101.38	100.25	99.13	98	96.87	95.75	94.62	93.49	92.37	91.24	90.11	88.99	87.86	86.73	85.61	1.12644—
102.41	101.27	100.14	99	97.83	96.72	95.59	94.45	93.31	92.17	91.03	89.90	88.76	87.62	86.48	1.13793+
103.45	102.30	101.15	100	98.85	97.70	96.55	95.40	94.25	93.10	91.95	90.80	89.65	88.50	87.35	1.14942+
104.48	103.32	102.16	101	99.84	98.68	97.52	96.36	95.19	94.03	92.87	91.71	90.55	89.39	88.23	1.16092—
105.52	104.34	103.17	102	100.83	99.65	98.48	97.31	96.14	94.96	93.79	92.62	91.45	90.27	89.10	1.17241+
106.55	105.37	104.18	103	101.82	100.63	99.45	98.26	97.08	95.90	94.71	93.53	92.34	91.16	89.98	1.18391—
107.59	106.39	105.19	104	102.80	101.61	100.41	99.22	98.02	96.83	95.63	94.44	93.24	92.04	90.85	1.19540+
108.62	107.41	106.21	105	103.79	102.59	101.38	100.17	98.96	97.76	96.55	95.34	94.14	92.93	91.72	1.20690—
109.66	108.44	107.22	106	104.78	103.56	102.34	101.13	99.91	98.69	97.47	96.25	95.03	93.82	92.60	1.21840—
110.69	109.46	108.23	107	105.77	104.54	103.31	102.08	100.85	99.62	98.39	97.16	95.93	94.70	93.47	1.22988+
111.72	110.48	109.24	108	106.75	105.52	104.27	103.03	101.79	100.55	99.31	98.07	96.83	95.59	94.34	1.24138—
112.76	111.50	110.25	109	107.75	106.49	105.24	103.99	102.73	101.48	100.23	98.98	97.72	96.47	95.22	1.25287+
113.79	112.53	111.26	110	108.73	107.47	106.21	104.94	103.68	102.41	101.15	99.88	98.62	97.36	96.09	1.26437—
114.83	113.55	112.27	111	109.72	108.45	107.17	105.90	104.62	103.34	102.07	100.79	99.53	98.24	96.96	1.27586+
115.86	114.57	113.29	112	110.71	109.42	108.14	106.85	105.56	104.28	102.99	101.70	100.41	99.13	97.84	1.28736+
116.90	115.60	114.30	113	111.70	110.40	109.10	107.80	106.50	105.21	103.91	102.61	101.31	100.01	98.71	1.29885—
117.93	116.62	115.31	114	112.69	111.38	110.07	108.76	107.45	106.14	104.83	103.52	102.21	100.90	99.58	1.31034+
118.96	117.64	116.32	115	113.68	112.36	111.03	109.71	108.39	107.07	105.75	104.42	103.10	101.78	100.46	1.32184—
120.00	118.67	117.33	116	114.67	113.33	112.00	110.67	109.33	108.00	106.67	105.33	104.00	102.67	101.33	1.33333+
121.03	119.69	118.34	117	115.65	114.31	112.96	111.62	110.28	108.93	107.59	106.24	104.90	103.55	102.21	1.34483—
122.07	120.71	119.36	118	116.64	115.29	113.93	112.57	111.22	109.86	108.50	107.15	105.79	104.44	103.08	1.35632+
123.10	121.73	120.37	119	117.63	116.26	114.90	113.53	112.16	110.79	109.42	108.05	106.69	105.32	103.95	1.36782—
124.14	122.76	121.38	120	118.62	117.24	115.86	114.48	113.10	111.72	110.34	108.96	107.59	106.21	104.83	1.37931

TABLE VI.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc.; showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 14 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
1.05	1.03	1.02	1.01	1	0.99	0.98	0.96	0.95	0.94	0.93	0.92	0.91	0.89	0.88	0.01163—
2.09	2.07	2.05	2.02	2	1.98	1.95	1.93	1.91	1.88	1.86	1.84	1.81	1.79	1.77	.02325+
3.14	3.10	3.07	3.03	3	2.96	2.93	2.89	2.86	2.82	2.79	2.75	2.72	2.68	2.65	.03488+
4.18	4.14	4.09	4.05	4	3.95	3.91	3.86	3.81	3.77	3.72	3.67	3.63	3.58	3.53	.04611+
5.23	5.17	5.12	5.06	5	4.94	4.88	4.82	4.77	4.71	4.65	4.59	4.53	4.48	4.42	.05814—
6.28	6.21	6.14	6.07	6	5.93	5.86	5.79	5.72	5.65	5.58	5.51	5.44	5.37	5.30	.06977—
7.32	7.24	7.16	7.08	7	6.92	6.84	6.75	6.67	6.59	6.51	6.43	6.35	6.27	6.18	.08139+
8.37	8.28	8.18	8.09	8	7.91	7.81	7.72	7.63	7.53	7.44	7.35	7.25	7.16	7.07	.09302+
9.42	9.31	9.21	9.10	9	8.99	8.89	8.79	8.68	8.58	8.48	8.37	8.27	8.16	8.06	.10465+
10.46	10.35	10.23	10.12	10	9.88	9.77	9.65	9.53	9.42	9.30	9.19	9.07	8.95	8.84	.11628—
11.51	11.38	11.26	11.13	11	10.87	10.74	10.62	10.49	10.36	10.23	10.10	9.98	9.85	9.72	.12791—
12.56	12.42	12.28	12.14	12	11.86	11.72	11.58	11.44	11.30	11.16	11.02	10.88	10.74	10.60	.13953+
13.60	13.45	13.30	13.15	13	12.85	12.70	12.55	12.39	12.24	12.09	11.94	11.79	11.64	11.49	.15116+
14.65	14.49	14.32	14.16	14	13.84	13.67	13.51	13.35	13.18	13.02	12.86	12.70	12.53	12.37	.16279—
15.70	15.52	15.35	15.17	15	14.82	14.65	14.48	14.30	14.13	13.95	13.78	13.60	13.43	13.25	.17442—
16.74	16.56	16.37	16.19	16	15.81	15.63	15.44	15.26	15.07	14.88	14.70	14.51	14.32	14.14	.18605+
17.79	17.59	17.39	17.20	17	16.80	16.60	16.41	16.21	16.01	15.81	15.61	15.42	15.22	15.02	.19767+
18.84	18.63	18.42	18.21	18	17.79	17.58	17.37	17.16	16.95	16.74	16.53	16.32	16.12	15.91	.20930+
19.88	19.66	19.44	19.22	19	18.78	18.56	18.34	18.12	17.89	17.67	17.45	17.23	17.01	16.79	.22093—
20.93	20.70	20.46	20.23	20	19.77	19.53	19.30	19.07	18.84	18.60	18.37	18.14	17.91	17.67	.23256—
21.98	21.73	21.49	21.24	21	20.76	20.51	20.27	20.02	19.78	19.53	19.29	19.05	18.80	18.56	.24419—
23.02	22.77	22.51	22.25	22	21.74	21.49	21.23	20.98	20.72	20.46	20.21	19.95	19.70	19.44	.25581+
24.07	23.80	23.53	23.27	23	22.73	22.46	22.20	21.93	21.66	21.39	21.13	20.86	20.59	20.32	.26744+
25.12	24.84	24.56	24.28	24	23.72	23.44	23.16	22.88	22.60	22.32	22.05	21.77	21.49	21.21	.27907—
26.16	25.87	25.58	25.29	25	24.71	24.42	24.13	23.84	23.55	23.26	22.96	22.67	22.38	22.09	.29070—
27.21	26.91	26.60	26.30	26	25.70	25.39	25.09	24.79	24.49	24.18	23.88	23.58	23.28	22.98	.30232+
28.25	27.94	27.63	27.31	27	26.68	26.37	26.06	25.74	25.43	25.12	24.80	24.49	24.17	23.86	.31395+
29.30	28.98	28.65	28.32	28	27.67	27.35	27.02	26.70	26.37	26.05	25.72	25.39	25.07	24.74	.32558+
30.35	30.01	29.67	29.34	29	28.66	28.32	27.99	27.65	27.31	26.98	26.64	26.30	25.96	25.63	.33721—
31.39	31.05	30.70	30.35	30	29.65	29.30	28.95	28.60	28.26	27.91	27.56	27.21	26.86	26.51	.34884—
32.44	32.08	31.72	31.36	31	30.64	30.28	29.92	29.56	29.20	28.84	28.48	28.11	27.75	27.39	.36046+
33.49	33.12	32.74	32.37	32	31.63	31.25	30.88	30.51	30.14	29.77	29.39	29.02	28.65	28.28	.37209+
34.53	34.15	33.77	33.38	33	32.62	32.23	31.85	31.46	31.08	30.70	30.31	29.93	29.55	29.16	.38372—
35.58	35.19	34.79	34.39	34	33.60	33.21	32.81	32.42	32.02	31.63	31.23	30.84	30.44	30.05	.39535+
36.63	36.22	35.81	35.41	35	34.59	34.19	33.78	33.37	32.96	32.56	32.15	31.74	31.34	30.93	.40698—
37.67	37.25	36.84	36.42	36	35.58	35.16	34.74	34.32	33.91	33.49	33.07	32.65	32.23	31.81	.41860+
38.72	38.29	37.86	37.43	37	36.57	36.14	35.71	35.28	34.85	34.42	33.99	33.56	33.13	32.70	.43023+
39.77	39.32	38.88	38.44	38	37.56	37.12	36.67	36.23	35.79	35.35	34.91	34.46	34.02	33.58	.44186—
40.81	40.36	39.91	39.45	39	38.55	38.09	37.64	37.19	36.73	36.28	35.82	35.37	34.92	34.46	.45349—
41.86	41.39	40.93	40.46	40	39.53	39.07	38.60	38.14	37.67	37.21	36.74	36.28	35.81	35.35	.46512—
42.91	42.43	41.95	41.48	41	40.52	40.05	39.57	39.09	38.61	38.14	37.66	37.18	36.71	36.23	.47674+
43.95	43.46	42.98	42.49	42	41.51	41.02	40.53	40.05	39.56	39.07	38.58	38.09	37.60	37.12	.48837+
45.00	44.50	44.00	43.50	43	42.50	42.00	41.50	41.00	40.50	40.00	39.50	39.00	38.50	38.00	.50000—
46.05	45.53	45.02	44.51	44	43.49	42.98	42.46	41.95	41.44	40.93	40.42	39.91	39.39	38.88	.51163+
47.09	46.57	46.05	45.52	45	44.48	43.95	43.43	42.91	42.38	41.86	41.34	40.81	40.29	39.77	.52325—
48.14	47.60	47.07	46.53	46	45.46	44.93	44.39	43.86	43.32	42.79	42.25	41.72	41.18	40.65	.53488+
49.18	48.64	48.09	47.55	47	46.45	45.91	45.36	44.81	44.27	43.72	43.17	42.63	42.08	41.53	.54651+
50.23	49.67	49.12	48.56	48	47.44	46.88	46.32	45.77	45.21	44.65	44.09	43.53	42.98	42.42	.55814—
51.28	50.71	50.14	49.57	49	48.43	47.86	47.29	46.72	46.15	45.58	45.01	44.44	43.87	43.30	.56977—
52.32	51.74	51.16	50.58	50	49.42	48.84	48.25	47.67	47.09	46.51	45.93	45.35	44.77	44.18	.58139+
53.37	52.78	52.18	51.59	51	50.41	49.81	49.22	48.63	48.03	47.44	46.85	46.25	45.66	45.07	.59302+
54.42	53.81	53.21	52.60	52	51.39	50.79	50.18	49.58	48.98	48.37	47.77	47.16	46.56	45.95	.60465+
55.46	54.85	54.23	53.62	53	52.38	51.77	51.15	50.53	49.92	49.30	48.69	48.07	47.45	46.84	.61628—
56.51	55.88	55.26	54.63	54	53.37	52.74	52.12	51.49	50.86	50.23	49.60	48.98	48.35	47.72	.62791—
57.56	56.92	56.28	55.64	55	54.36	53.72	53.08	52.44	51.80	51.16	50.52	49.88	49.24	48.60	.63953+
58.60	57.95	57.30	56.65	56	55.35	54.70	54.05	53.39	52.74	52.09	51.44	50.79	50.14	49.49	.65116+
59.65	58.99	58.32	57.66	57	56.34	55.67	55.01	54.35	53.68	53.02	52.36	51.70	51.03	50.37	.66279—
60.70	60.02	59.35	58.67	58	57.32	56.65	55.98	55.30	54.63	53.95	53.28	52.60	51.93	51.25	.67442—
61.74	61.06	60.37	59.69	59	58.31	57.63	56.94	56.26	55.57	54.88	54.20	53.51	52.82	52.14	.68605+
62.79	62.09	61.39	60.70	60	59.30	58.60	57.91	57.21	56.51	55.81	55.11	54.42	53.72	53.02	.69767—

TABLE VI.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 14 per cent in moisture is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
63.84	63.13	62.42	61.71	61	60.29	59.58	58.87	58.16	57.45	56.74	56.03	55.32	54.62	53.91	0.70930+
64.88	64.16	63.44	62.72	62	61.28	60.56	59.84	59.12	58.39	57.67	56.95	56.23	55.51	54.79	.72093
65.93	65.20	64.46	63.73	63	62.27	61.53	60.80	60.07	59.34	58.60	57.87	57.14	56.41	55.67	.73256+
66.98	66.23	65.49	64.74	64	63.26	62.51	61.77	61.02	60.28	59.53	58.79	58.05	57.30	56.56	.74419
68.02	67.27	66.51	65.75	65	64.24	63.49	62.73	61.98	61.22	60.46	59.71	58.95	58.20	57.44	.75581+
69.07	68.30	67.53	66.77	66	65.23	64.46	63.70	62.93	62.16	61.39	60.63	59.86	59.09	58.32	.76744+
70.12	69.34	68.56	67.78	67	66.22	65.44	64.66	63.88	63.10	62.32	61.55	60.77	59.99	59.21	.77907
71.16	70.37	69.58	68.79	68	67.21	66.42	65.63	64.84	64.05	63.26	62.46	61.67	60.88	60.09	.79070
72.21	71.41	70.60	69.80	69	68.20	67.39	66.59	65.79	64.99	64.18	63.38	62.58	61.78	60.98	.80232+
73.25	72.44	71.63	70.81	70	69.18	68.37	67.56	66.74	65.93	65.12	64.30	63.49	62.67	61.86	.81395+
74.30	73.48	72.65	71.82	71	70.17	69.35	68.52	67.70	66.87	66.05	65.22	64.39	63.57	62.74	.82558+
75.35	74.51	73.67	72.84	72	71.16	70.32	69.49	68.65	67.81	66.98	66.14	65.30	64.46	63.63	.83721+
76.39	75.55	74.70	73.85	73	72.15	71.30	70.45	69.60	68.76	67.91	67.06	66.21	65.36	64.51	.84884
77.44	76.58	75.72	74.86	74	73.14	72.28	71.42	70.56	69.70	68.84	67.98	67.11	66.25	65.39	.86046+
78.49	77.62	76.74	75.87	75	74.13	73.25	72.38	71.51	70.64	69.77	68.89	68.02	67.15	66.28	.87209+
79.53	78.65	77.77	76.88	76	75.12	74.23	73.35	72.46	71.58	70.70	69.81	68.93	68.05	67.16	.88372
80.58	79.69	78.79	77.89	77	76.10	75.21	74.31	73.42	72.52	71.63	70.73	69.84	68.94	68.05	.89535
81.63	80.72	79.81	78.91	78	77.09	76.19	75.28	74.37	73.46	72.56	71.65	70.74	69.84	68.93	.90698
82.67	81.75	80.84	79.92	79	78.08	77.16	76.24	75.32	74.41	73.49	72.57	71.65	70.73	69.81	.91860+
83.72	82.79	81.86	80.93	80	79.07	78.14	77.21	76.28	75.35	74.42	73.49	72.56	71.63	70.70	.93023+
84.77	83.82	82.88	81.94	81	80.06	79.12	78.17	77.23	76.29	75.35	74.41	73.46	72.52	71.58	.94186
85.81	84.86	83.91	82.95	82	81.05	80.09	79.14	78.19	77.23	76.28	75.32	74.37	73.42	72.46	.95349
86.86	85.89	84.93	83.96	83	82.03	81.07	80.10	79.14	78.17	77.21	76.24	75.28	74.31	73.35	.96512
87.91	86.93	85.95	84.98	84	83.02	82.05	81.07	80.09	79.11	78.14	77.16	76.18	75.21	74.23	.97674+
88.95	87.96	86.98	85.99	85	84.01	83.02	82.03	81.05	80.06	79.07	78.08	77.09	76.10	75.12	.98837+
89.99	89.00	88.00	87.00	86	85.00	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000
91.03	90.03	89.02	88.01	87	85.99	84.98	83.96	82.95	81.94	80.93	79.92	78.91	77.89	76.88	1.01163
92.09	91.07	90.05	89.02	88	86.98	85.95	84.93	83.91	82.88	81.86	80.84	79.81	78.79	77.77	1.02325
93.14	92.10	91.07	90.03	89	87.96	86.93	85.89	84.86	83.82	82.79	81.75	80.72	79.68	78.65	1.03488+
94.18	93.14	92.09	91.05	90	88.95	87.91	86.86	85.81	84.77	83.72	82.67	81.63	80.58	79.53	1.04651+
95.23	94.17	93.12	92.06	91	89.94	88.88	87.82	86.77	85.71	84.65	83.59	82.53	81.48	80.42	1.05814
96.28	95.21	94.14	93.07	92	90.93	89.86	88.79	87.72	86.65	85.58	84.51	83.44	82.37	81.30	1.06977
97.32	96.24	95.16	94.08	93	91.92	90.84	89.75	88.67	87.59	86.51	85.43	84.35	83.27	82.18	1.08139+
98.37	97.28	96.18	95.09	94	92.91	91.81	90.72	89.63	88.53	87.44	86.35	85.25	84.16	83.07	1.09302
99.42	98.31	97.21	96.10	95	93.91	92.79	91.68	90.58	89.48	88.37	87.27	86.16	85.06	83.95	1.10465+
100.46	99.35	98.23	97.12	96	94.88	93.77	92.65	91.53	90.42	89.30	88.19	87.07	85.95	84.84	1.11628
101.51	100.38	99.26	98.13	97	95.87	94.74	93.62	92.49	91.36	90.24	89.10	87.98	86.85	85.72	1.12791
102.56	101.42	100.27	99.14	98	96.86	95.72	94.58	93.44	92.30	91.16	90.02	88.88	87.74	86.60	1.13953+
103.60	102.45	101.30	100.15	99	97.85	96.70	95.55	94.39	93.24	92.09	90.94	89.79	88.64	87.49	1.15116
104.65	103.49	102.32	101.16	100	98.84	97.67	96.51	95.35	94.18	93.02	91.86	90.70	89.53	88.37	1.16279
105.70	104.52	103.35	102.17	101	99.82	98.65	97.48	96.30	95.13	93.95	92.78	91.60	90.43	89.25	1.17442
106.74	105.56	104.37	103.19	102	100.81	99.63	98.44	97.26	96.07	94.88	93.70	92.51	91.32	90.14	1.18605
107.79	106.59	105.39	104.20	103	101.80	100.60	99.41	98.21	97.01	95.81	94.61	93.42	92.22	91.02	1.19767+
108.84	107.63	106.42	105.21	104	102.79	101.58	100.37	99.16	97.95	96.74	95.53	94.32	93.12	91.91	1.20930
109.88	108.66	107.44	106.22	105	103.78	102.56	101.34	100.12	98.90	97.67	96.45	95.23	94.01	92.79	1.22093
110.93	109.70	108.46	107.23	106	104.77	103.53	102.30	101.07	99.84	98.60	97.37	96.14	94.91	93.67	1.23256
111.98	110.73	109.49	108.24	107	105.76	104.51	103.27	102.02	100.78	99.53	98.29	97.05	95.80	94.56	1.24419
113.02	111.77	110.51	109.25	108	106.74	105.49	104.23	102.98	101.72	100.46	99.21	97.95	96.70	95.44	1.25581
114.07	112.80	111.53	110.27	109	107.73	106.46	105.20	103.93	102.66	101.39	100.13	98.86	97.59	96.32	1.26744
115.12	113.84	112.56	111.28	110	108.72	107.44	106.16	104.88	103.60	102.32	101.05	99.77	98.49	97.21	1.27907
116.16	114.87	113.58	112.29	111	109.71	108.42	107.13	105.84	104.55	103.26	101.96	100.67	99.38	98.09	1.29070
117.21	115.91	114.60	113.30	112	110.70	109.39	108.09	106.79	105.49	104.18	102.88	101.58	100.28	98.98	1.30232+
118.25	116.94	115.63	114.31	113	111.68	110.37	109.06	107.74	106.43	105.12	103.80	102.49	101.17	99.86	1.31395+
119.30	117.98	116.65	115.32	114	112.67	111.35	110.02	108.70	107.37	106.05	104.72	103.39	102.07	100.74	1.32558
120.35	119.01	117.67	116.34	115	113.66	112.32	110.99	109.65	108.31	106.98	105.64	104.30	102.96	101.63	1.33721
121.39	120.05	118.70	117.35	116	114.65	113.30	111.95	110.60	109.26	107.91	106.56	105.21	103.86	102.51	1.34884
122.44	121.08	119.72	118.36	117	115.64	114.28	112.92	111.56	110.20	108.84	107.48	106.11	104.75	103.39	1.36046
123.49	122.12	120.76	119.37	118	116.63	115.25	113.88	112.51	111.14	109.77	108.39	107.02	105.65	104.28	1.37209+
124.53	123.15	121.77	120.38	119	117.62	116.23	114.85	113.46	112.08	110.70	109.31	107.93	106.55	105.16	1.38372
125.58	124.19	122.79	121.39	120	118.60	117.21	115.81	114.42	113.02	111.63	110.23	108.84	107.44	106.05	1.39535

TABLE VII.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc.; showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 15 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
1.06	1.05	1.03	1.02	1.01	1	0.99	0.98	0.96	0.95	0.94	0.93	0.92	0.90	0.89	0.01176+
2.12	2.09	2.07	2.05	2.02	2	1.98	1.95	1.93	1.90	1.88	1.86	1.83	1.81	1.79	.02353-
3.18	3.14	3.10	3.07	3.03	3	2.96	2.93	2.89	2.86	2.82	2.79	2.75	2.72	2.68	.03529+
4.23	4.19	4.14	4.09	4.05	4	3.95	3.90	3.86	3.81	3.76	3.72	3.67	3.62	3.58	.04706-
5.29	5.23	5.18	5.12	5.06	5	4.94	4.88	4.82	4.76	4.70	4.65	4.59	4.53	4.47	.05882+
6.35	6.28	6.21	6.14	6.07	6	5.93	5.86	5.79	5.72	5.65	5.58	5.51	5.43	5.36	.07059-
7.41	7.33	7.25	7.16	7.08	7	6.92	6.83	6.75	6.67	6.59	6.50	6.42	6.34	6.26	.08235+
8.47	8.38	8.28	8.19	8.09	8	7.91	7.81	7.72	7.62	7.53	7.43	7.34	7.25	7.15	.09412-
9.53	9.42	9.32	9.21	9.10	9	8.99	8.79	8.68	8.58	8.47	8.36	8.26	8.15	8.05	.10588+
10.59	10.47	10.35	10.23	10.12	10	9.88	9.70	9.65	9.53	9.41	9.29	9.18	9.06	8.94	.11765-
11.65	11.52	11.39	11.26	11.13	11	10.87	10.74	10.61	10.48	10.35	10.22	10.09	9.96	9.83	.12941+
12.71	12.56	12.42	12.28	12.14	12	11.86	11.72	11.58	11.43	11.29	11.15	11.01	10.87	10.73	.14118-
13.76	13.61	13.46	13.30	13.15	13	12.85	12.70	12.54	12.39	12.23	12.08	11.93	11.78	11.62	.15294+
14.82	14.66	14.49	14.33	14.16	14	13.83	13.67	13.50	13.34	13.18	13.01	12.85	12.68	12.52	.16470+
15.88	15.70	15.53	15.35	15.18	15	14.82	14.65	14.47	14.29	14.12	13.94	13.76	13.59	13.41	.17647+
16.94	16.75	16.56	16.38	16.19	16	15.81	15.62	15.43	15.25	15.06	14.87	14.68	14.49	14.30	.18823+
18.00	17.80	17.60	17.40	17.21	17	16.83	16.60	16.40	16.23	16.00	15.80	15.60	15.40	15.20	.20000
19.06	18.85	18.63	18.42	18.21	18	17.79	17.58	17.36	17.15	16.94	16.73	16.52	16.30	16.09	.21176+
20.12	19.89	19.67	19.45	19.22	19	18.78	18.55	18.33	18.10	17.88	17.66	17.43	17.21	16.99	.22353-
21.18	20.94	20.70	20.47	20.23	20	19.76	19.52	19.29	19.06	18.82	18.59	18.35	18.12	17.88	.23529+
22.23	21.99	21.74	21.49	21.25	21	20.75	20.50	20.26	20.01	19.76	19.52	19.27	19.02	18.77	.24706-
23.29	23.03	22.78	22.52	22.26	22	21.74	21.48	21.22	20.96	20.70	20.45	20.19	19.93	19.67	.25882+
24.35	24.08	23.81	23.54	23.27	23	22.73	22.46	22.19	21.92	21.65	21.38	21.11	20.83	20.56	.27059-
25.41	25.13	24.85	24.56	24.28	24	23.72	23.43	23.15	22.87	22.59	22.30	22.02	21.74	21.46	.28235+
26.47	26.18	25.88	25.59	25.29	25	24.71	24.41	24.12	23.82	23.53	23.23	22.93	22.62	22.35	.29412-
27.53	27.22	26.92	26.61	26.30	26	25.69	25.39	25.08	24.78	24.47	24.16	23.86	23.55	23.25	.30588+
28.59	28.27	27.95	27.63	27.32	27	26.68	26.36	26.05	25.73	25.41	25.09	24.78	24.46	24.14	.31765-
29.65	29.32	28.99	28.66	28.33	28	27.67	27.34	27.01	26.68	26.35	26.02	25.69	25.36	25.03	.32941+
30.71	30.36	30.02	29.68	29.34	29	28.66	28.32	27.98	27.63	27.29	26.95	26.61	26.27	25.93	.34118-
31.76	31.41	31.06	30.70	30.35	30	29.65	29.29	28.94	28.59	28.23	27.88	27.53	27.18	26.82	.35294+
32.82	32.46	32.09	31.73	31.36	31	30.63	30.27	29.90	29.54	29.18	28.81	28.45	28.08	27.72	.36470+
33.88	33.50	33.13	32.75	32.38	32	31.62	31.25	30.87	30.49	30.12	29.74	29.36	28.99	28.61	.37647
34.94	34.55	34.16	33.78	33.39	33	32.61	32.22	31.83	31.45	31.06	30.67	30.28	29.89	29.50	.38823+
36.00	35.60	35.20	34.80	34.40	34	33.60	33.20	32.80	32.40	32.00	31.60	31.21	30.80	30.40	.40000
37.06	36.65	36.23	35.82	35.41	35	34.59	34.18	33.76	33.35	32.94	32.53	32.12	31.70	31.29	.41176+
38.12	37.69	37.27	36.85	36.42	36	35.58	35.15	34.73	34.30	33.88	33.46	33.03	32.61	32.19	.42353-
39.18	38.74	38.30	37.87	37.43	37	36.56	36.13	35.69	35.26	34.82	34.39	33.95	33.52	33.08	.43529+
40.23	39.79	39.34	38.89	38.45	38	37.55	37.10	36.66	36.21	35.76	35.32	34.87	34.42	33.98	.44706-
41.29	40.83	40.38	39.92	39.46	39	38.51	38.08	37.62	37.16	36.70	36.25	35.79	35.33	34.87	.45882+
42.35	41.88	41.41	40.94	40.47	40	39.53	39.06	38.59	38.12	37.65	37.18	36.71	36.23	35.76	.47059-
43.41	42.93	42.45	41.96	41.48	41	40.52	40.03	39.55	39.07	38.59	38.10	37.62	37.14	36.66	.48235+
44.47	43.98	43.48	42.99	42.49	42	41.51	41.01	40.52	40.02	39.53	39.03	38.54	38.05	37.55	.49412-
45.53	45.02	44.52	44.01	43.50	43	42.49	41.99	41.48	40.98	40.47	39.96	39.46	38.95	38.45	.50588+
46.59	46.07	45.55	45.03	44.52	44	43.48	42.96	42.45	41.93	41.41	40.89	40.38	39.86	39.34	.51765-
47.65	47.12	46.59	46.06	45.53	45	44.47	43.94	43.41	42.88	42.35	41.82	41.29	40.76	40.23	.52941+
48.71	48.16	47.62	47.08	46.54	46	45.46	44.92	44.38	43.83	43.29	42.75	42.21	41.67	41.13	.54118-
49.76	49.21	48.66	48.10	47.55	47	46.45	45.89	45.31	44.79	44.23	43.68	43.13	42.58	42.02	.55294+
50.82	50.26	49.69	49.13	48.56	48	47.43	46.87	46.30	45.74	45.18	44.61	44.05	43.48	42.92	.56470+
51.88	51.30	50.73	50.15	49.58	49	48.42	47.85	47.27	46.69	46.12	45.54	44.96	44.39	43.81	.57647
52.94	52.35	51.76	51.18	50.59	50	49.41	48.82	48.23	47.65	47.06	46.47	45.88	45.29	44.70	.58823+
54.00	53.40	52.80	52.20	51.60	51	50.40	49.80	49.20	48.60	48.00	47.40	46.80	46.20	45.60	.60000
55.06	54.45	53.83	53.22	52.61	52	51.39	50.78	50.16	49.55	48.94	48.33	47.72	47.10	46.49	.61176+
56.12	55.49	54.87	54.25	53.62	53	52.38	51.75	51.13	50.50	49.88	49.26	48.63	48.01	47.39	.62353-
57.18	56.54	55.90	55.27	54.63	54	53.36	52.73	52.09	51.46	50.82	50.19	49.55	48.92	48.28	.63529+
58.23	57.59	56.94	56.29	55.65	55	54.35	53.70	53.06	52.41	51.76	51.12	50.47	49.82	49.18	.64706-
59.29	58.63	57.98	57.32	56.66	56	55.34	54.68	54.02	53.36	52.70	52.05	51.39	50.73	50.07	.65882+
60.35	59.68	59.01	58.34	57.67	57	56.33	55.66	54.99	54.32	53.65	52.98	52.31	51.63	50.96	.67059-
61.41	60.73	60.05	59.36	58.68	58	57.32	56.63	55.95	55.27	54.59	53.90	53.22	52.54	51.86	.68235+
62.47	61.78	61.08	60.39	59.69	59	58.31	57.61	56.92	56.22	55.53	54.83	54.14	53.45	52.75	.69412-
63.53	62.82	62.12	61.41	60.70	60	59.29	58.59	57.88	57.18	56.47	55.76	55.06	54.35	53.65	.70588+

TABLE VII.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 15 per cent in moisture is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.																Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>	
64.59	63.87	63.15	62.43	61.72	61	60.28	59.56	58.85	58.13	57.41	56.69	55.98	55.26	54.54	0.71765—	
65.65	64.92	64.19	63.46	62.73	62	61.27	60.54	59.81	59.08	58.35	57.62	56.89	56.16	55.43	.72941+	
66.61	65.96	65.22	64.48	63.74	63	62.26	61.52	60.78	60.03	59.29	58.55	57.81	57.07	56.33	.74118+	
67.76	67.01	66.26	65.50	64.75	64	63.25	62.49	61.74	60.99	60.23	59.48	58.73	57.98	57.22	.75294+	
68.82	68.06	67.29	66.53	65.76	65	64.23	63.47	62.70	61.94	61.18	60.41	59.65	58.88	58.12	.76470+	
69.88	69.10	68.33	67.55	66.78	66	65.22	64.45	63.67	62.89	62.12	61.34	60.56	58.79	59.01	.77647	
70.94	70.15	69.36	68.58	67.79	67	66.21	65.42	64.63	63.85	63.06	62.27	61.48	60.69	59.90	.78823+	
72.00	71.20	70.40	69.60	68.80	68	67.20	66.40	65.60	64.80	64.00	63.20	62.40	61.60	60.80	.80000	
73.06	72.25	71.43	70.62	69.81	69	68.19	67.38	66.56	65.75	64.94	64.13	63.32	62.50	61.69	.81176+	
74.12	73.29	72.47	71.65	70.82	70	69.18	68.35	67.53	66.70	65.88	65.06	64.23	63.41	62.59	.82353—	
75.18	74.34	73.50	72.67	71.83	71	70.16	69.33	68.49	67.66	66.82	65.99	65.15	64.32	63.48	.83529+	
76.23	75.39	74.54	73.69	72.85	72	71.15	70.30	69.46	68.61	67.76	66.92	66.07	65.22	64.38	.84706—	
77.29	76.43	75.58	74.72	73.86	73	72.14	71.28	70.42	69.56	68.70	67.85	66.99	66.13	65.27	.85882+	
78.35	77.48	76.61	75.74	74.87	74	73.13	72.26	71.39	70.52	69.65	68.78	67.91	67.03	66.16	.87059—	
79.41	78.53	77.65	76.76	75.88	75	74.12	73.23	72.35	71.47	70.59	69.70	68.82	67.94	67.06	.88235+	
80.47	79.58	78.68	77.79	76.89	76	75.11	74.21	73.32	72.42	71.53	70.63	69.74	68.85	67.95	.89412—	
81.53	80.62	79.72	78.81	77.90	77	76.09	75.19	74.28	73.38	72.47	71.56	70.66	69.75	68.85	.90588+	
82.59	81.67	80.75	79.83	78.92	78	77.08	76.16	75.25	74.33	73.41	72.49	71.58	70.66	69.74	.91765+	
83.65	82.72	81.79	80.87	79.93	79	78.07	77.14	76.21	75.28	74.35	73.42	72.49	71.56	70.63	.92941+	
84.71	83.76	82.82	81.88	80.94	80	79.06	78.12	77.18	76.23	75.29	74.35	73.41	72.47	71.53	.94118—	
85.76	84.81	83.86	82.90	81.95	81	80.05	79.09	78.14	77.19	76.23	75.28	74.33	73.38	72.42	.95294+	
86.82	85.86	84.89	83.93	82.96	82	81.03	80.07	79.10	78.14	77.18	76.21	75.25	74.28	73.32	.96470+	
87.88	86.91	85.93	84.95	83.98	83	82.02	81.05	80.07	79.09	78.12	77.14	76.16	75.19	74.21	.97647	
88.91	87.95	86.96	85.98	84.99	84	83.01	82.02	81.03	80.05	79.06	78.07	77.08	76.09	75.10	.98823+	
90.00	89.00	88.00	87.00	86.00	85	84.00	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000	
91.06	90.05	89.03	88.02	87.01	86	84.99	83.98	82.96	81.95	80.94	79.93	78.92	77.90	76.89	1.01176+	
92.12	91.09	90.07	89.05	88.02	87	85.98	84.95	83.93	82.90	81.88	80.86	79.83	78.81	77.79	1.02353—	
93.18	92.14	91.10	90.07	89.03	88	86.96	85.93	84.89	83.86	82.82	81.79	80.75	79.72	78.68	1.03529+	
94.23	93.19	92.14	91.09	90.05	89	87.95	86.90	85.86	84.81	83.76	82.72	81.67	80.62	79.58	1.04706—	
95.29	94.23	93.18	92.12	91.06	90	88.94	87.88	86.82	85.76	84.70	83.65	82.59	81.53	80.47	1.05882+	
96.35	95.28	94.21	93.14	92.07	91	89.93	88.86	87.79	86.72	85.65	84.58	83.51	82.43	81.36	1.07059—	
97.41	96.33	95.25	94.16	93.08	92	90.92	89.83	88.75	87.67	86.59	85.50	84.42	83.34	82.26	1.08235+	
98.47	97.38	96.28	95.19	94.09	93	91.91	90.81	89.72	88.62	87.53	86.43	85.34	84.25	83.15	1.09412—	
99.53	98.42	97.32	96.21	95.10	94	92.89	91.79	90.68	89.58	88.47	87.36	86.26	85.15	84.05	1.10588+	
100.59	99.47	98.35	97.23	96.12	95	93.88	92.76	91.65	90.53	89.41	88.29	87.18	86.06	84.94	1.11765—	
101.65	100.52	99.39	98.26	97.13	96	94.87	93.74	92.61	91.48	90.35	89.22	88.09	86.96	85.83	1.12941+	
102.71	101.56	100.42	99.28	98.14	97	95.86	94.72	93.58	92.43	91.29	90.15	89.01	87.87	86.73	1.14118—	
103.76	102.61	101.46	100.30	99.15	98	96.85	95.69	94.54	93.39	92.23	91.08	89.93	88.78	87.62	1.15294+	
104.82	103.66	102.49	101.33	100.16	99	97.83	96.67	95.50	94.34	93.18	92.01	90.85	89.68	88.52	1.16470+	
105.88	104.70	103.53	102.35	101.18	100	98.82	97.65	96.47	95.29	94.12	92.94	91.76	90.59	89.41	1.17647	
106.94	105.75	104.56	103.38	102.19	101	99.81	98.62	97.43	96.25	95.06	93.87	92.68	91.49	90.30	1.18823+	
108.00	106.80	105.60	104.40	103.20	102	100.80	99.60	98.40	97.20	96.00	94.80	93.60	92.40	91.20	1.20000	
109.06	107.85	106.63	105.42	104.21	103	101.79	100.58	99.36	98.15	96.94	95.73	94.52	93.30	92.09	1.21176+	
110.12	108.89	107.67	106.45	105.22	104	102.78	101.55	100.33	99.10	97.88	96.66	95.43	94.21	92.99	1.22353—	
111.18	109.94	108.70	107.47	106.23	105	103.76	102.53	101.29	100.06	98.82	97.59	96.35	95.12	93.88	1.23529+	
112.23	110.99	109.74	108.49	107.25	106	104.75	103.50	102.26	101.01	99.76	98.52	97.27	96.02	94.78	1.24706—	
113.29	112.03	110.78	109.52	108.26	107	105.74	104.48	103.22	101.96	100.70	99.45	98.19	96.93	95.67	1.25882+	
114.35	113.08	111.81	110.54	109.27	108	106.73	105.46	104.19	102.92	101.65	100.38	99.11	97.83	96.56	1.27059—	
115.41	114.13	112.85	111.56	110.28	107	107.72	106.43	105.15	103.87	102.59	101.30	99.99	98.74	97.46	1.28235+	
116.47	115.18	113.88	112.59	111.29	110	108.71	107.41	106.12	104.82	103.53	102.23	100.94	99.65	98.35	1.29412—	
117.53	116.22	114.92	113.61	112.30	111	109.69	108.38	107.08	105.78	104.47	103.16	101.86	100.55	99.25	1.30588+	
118.59	117.27	115.95	114.63	113.32	112	110.68	109.36	108.05	106.73	105.41	104.09	102.78	101.46	100.14	1.31765—	
119.65	118.32	116.99	115.66	114.33	113	111.67	110.34	109.01	107.68	106.35	105.02	103.69	102.36	101.03	1.32941+	
120.71	119.36	118.02	116.68	115.34	114	112.66	111.32	109.98	108.63	107.29	105.95	104.61	103.27	101.93	1.34118—	
121.76	120.41	119.06	117.70	116.35	115	113.65	112.29	110.94	109.59	108.23	106.88	105.53	104.18	102.82	1.35294+	
122.82	121.46	120.09	118.73	117.36	116	114.63	113.27	111.90	110.54	109.18	107.81	106.45	105.08	103.72	1.36470+	
123.88	122.50	121.13	119.75	118.38	117	115.62	114.25	112.87	111.49	110.12	108.74	107.36	105.99	104.61	1.37647	
124.94	123.55	122.16	120.78	119.39	118	116.61	115.22	113.83	112.45	111.06	109.67	108.28	106.89	105.50	1.38823+	
126.00	124.60	123.20	121.80	120.40	119	117.60	116.20	114.80	113.40	112.00	110.60	109.20	107.80	106.40	1.40000	
127.06	125.65	124.23	122.82	121.41	120	118.59	117.18	115.76	114.35	112.94	111.53	110.12	108.70	107.29	1.41176+	

TABLE VIII.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 16 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.																	Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
1.07	1.06	1.05	1.03	1.02	1.01	1	0.99	0.97	0.96	0.95	0.94	0.93	0.92	0.90	0.89	0.88	0.11190+
2.14	2.12	2.09	2.07	2.05	2.02	2	1.98	1.95	1.93	1.90	1.88	1.86	1.83	1.81	1.80	1.79	.02381—
3.21	3.18	3.14	3.11	3.07	3.03	3	2.96	2.93	2.89	2.86	2.82	2.78	2.75	2.71	2.70	2.69	.03571+
4.28	4.24	4.19	4.14	4.09	4.05	4	3.95	3.90	3.86	3.81	3.76	3.71	3.67	3.62	3.61	3.60	.04762—
5.36	5.30	5.24	5.18	5.12	5.06	5	4.94	4.88	4.82	4.76	4.70	4.64	4.58	4.52	4.51	4.50	.05952+
6.43	6.36	6.28	6.21	6.14	6.07	6	5.93	5.86	5.78	5.71	5.64	5.57	5.50	5.43	5.42	5.41	.07143—
7.50	7.42	7.33	7.25	7.17	7.08	7	6.92	6.83	6.75	6.67	6.58	6.50	6.42	6.33	6.32	6.31	.08333+
8.57	8.48	8.38	8.28	8.19	8.09	8	7.90	7.81	7.71	7.62	7.52	7.43	7.33	7.24	7.23	7.22	.09524—
9.64	9.53	9.43	9.32	9.21	9.11	9	8.89	8.78	8.68	8.57	8.46	8.36	8.25	8.14	8.13	8.12	.10714+
10.71	10.59	10.45	10.36	10.24	10.12	10	9.88	9.76	9.64	9.52	9.40	9.28	9.17	9.05	9.04	9.03	.11905—
11.78	11.65	11.52	11.39	11.26	11.13	11	10.87	10.74	10.61	10.48	10.34	10.21	10.08	9.95	9.94	9.93	.13095+
12.86	12.71	12.57	12.43	12.28	12.14	12	11.86	11.71	11.57	11.43	11.28	11.14	11.00	10.86	10.85	10.84	.14286—
13.93	13.77	13.62	13.46	13.31	13.15	13	12.84	12.69	12.53	12.38	12.23	12.07	11.92	11.76	11.75	11.74	.15476+
15.00	14.83	14.67	14.50	14.33	14.17	14	13.83	13.67	13.50	13.33	13.17	13.00	12.83	12.67	12.66	12.65	.16667—
16.07	15.89	15.71	15.53	15.36	15.18	15	14.82	14.64	14.46	14.28	14.11	13.93	13.75	13.57	13.56	13.55	.17857+
17.14	16.95	16.76	16.57	16.38	16.19	16	15.81	15.62	15.43	15.24	15.05	14.86	14.67	14.48	14.47	14.46	.19048—
18.21	18.01	17.81	17.61	17.40	17.20	17	16.80	16.59	16.39	16.19	15.99	15.78	15.58	15.38	15.37	15.36	.20238
19.28	19.07	18.86	18.64	18.43	18.21	18	17.78	17.57	17.36	17.14	16.93	16.71	16.50	16.28	16.27	16.26	.21428+
20.36	20.13	19.90	19.68	19.45	19.23	19	18.77	18.55	18.32	18.09	17.87	17.64	17.42	17.19	17.18	17.17	.22619
21.43	21.19	20.95	20.71	20.47	20.24	20	19.76	19.52	19.28	19.05	18.81	18.57	18.33	18.09	18.08	18.07	.23809+
22.50	22.25	22.00	21.75	21.50	21.25	21	20.75	20.50	20.25	20.00	19.75	19.50	19.25	19.00	18.99	18.98	.25000
23.57	23.31	23.05	22.78	22.52	22.26	22	21.74	21.47	21.21	20.95	20.69	20.43	20.17	19.90	19.89	19.88	.26190+
24.64	24.37	24.09	23.82	23.55	23.28	23	22.73	22.45	22.18	21.90	21.63	21.36	21.08	20.81	20.80	20.79	.27381—
25.71	25.43	25.14	24.86	24.57	24.28	24	23.71	23.43	23.14	22.86	22.57	22.28	22.00	21.71	21.70	21.69	.28571+
26.78	26.49	26.19	25.89	25.59	25.29	25	24.70	24.40	24.11	23.81	23.51	23.21	22.92	22.62	22.61	22.60	.29762—
27.86	27.55	27.24	26.93	26.62	26.31	26	25.69	25.38	25.07	24.76	24.45	24.14	23.83	23.52	23.51	23.50	.30952+
28.93	28.61	28.28	27.96	27.64	27.32	27	26.68	26.36	26.03	25.71	25.39	25.07	24.75	24.43	24.42	24.41	.32143—
30.00	29.67	29.33	29.00	28.67	28.33	28	27.67	27.33	27.00	26.67	26.33	26.00	25.67	25.33	25.32	25.31	.33333+
31.07	30.73	30.38	30.03	29.69	29.34	29	28.65	28.31	27.97	27.62	27.27	26.93	26.58	26.24	26.23	26.22	.34524—
32.14	31.78	31.43	31.07	30.71	30.36	30	29.64	29.28	28.93	28.57	28.21	27.86	27.50	27.14	27.13	27.12	.35714+
33.21	32.84	32.48	32.11	31.74	31.37	31	30.63	30.26	29.89	29.52	29.15	28.78	28.42	28.05	28.04	28.03	.36905—
34.28	33.90	33.52	33.14	32.76	32.38	32	31.62	31.24	30.86	30.48	30.09	29.71	29.33	28.95	28.94	28.93	.38095+
35.36	34.96	34.57	34.18	33.78	33.39	33	32.61	32.21	31.82	31.43	31.03	30.64	30.25	29.86	29.85	29.84	.39286—
36.43	36.02	35.62	35.21	34.81	34.40	34	33.59	33.19	32.78	32.38	31.98	31.57	31.17	30.76	30.75	30.74	.40476+
37.50	37.08	36.67	36.25	35.83	35.42	35	34.58	34.17	33.75	33.33	32.92	32.50	32.08	31.67	31.66	31.65	.41667—
38.57	38.14	37.71	37.28	36.86	36.43	36	35.57	35.14	34.71	34.28	33.86	33.43	33.00	32.57	32.56	32.55	.42857+
39.64	39.20	38.76	38.32	37.88	37.44	37	36.56	36.12	35.68	35.24	34.80	34.36	33.92	33.48	33.47	33.46	.44048—
40.71	40.26	39.81	39.36	38.90	38.45	38	37.55	37.09	36.64	36.19	35.74	35.28	34.83	34.38	34.37	34.36	.45238+
41.78	41.32	40.86	40.39	39.93	39.46	39	38.53	38.07	37.61	37.14	36.68	36.21	35.75	35.28	35.27	35.26	.46428+
42.86	42.38	41.90	41.43	40.95	40.48	40	39.52	39.05	38.57	38.09	37.62	37.14	36.67	36.19	36.18	36.17	.47619
43.93	43.44	42.95	42.46	41.97	41.49	41	40.51	40.02	39.53	39.05	38.56	38.07	37.58	37.09	37.08	37.07	.48809+
45.00	44.50	44.00	43.50	43.00	42.50	42	41.50	41.00	40.50	40.00	39.50	39.00	38.50	38.00	37.99	37.98	.50000
46.07	45.56	45.05	44.53	44.02	43.51	43	42.49	41.97	41.46	40.95	40.44	39.93	39.42	38.90	38.89	38.88	.51190+
47.14	46.62	46.09	45.57	45.05	44.52	44	43.48	42.95	42.43	41.90	41.38	40.86	40.33	39.81	39.80	39.79	.52381—
48.21	47.68	47.14	46.61	46.07	45.53	45	44.46	43.93	43.39	42.86	42.32	41.78	41.25	40.71	40.70	40.69	.53571+
49.28	48.74	48.19	47.64	47.09	46.55	46	45.45	44.90	44.36	43.81	43.26	42.71	42.17	41.62	41.61	41.60	.54762—
50.36	49.80	49.24	48.68	48.12	47.56	47	46.44	45.88	45.32	44.76	44.20	43.64	43.08	42.52	42.51	42.50	.55952+
51.43	50.86	50.28	49.71	49.14	48.57	48	47.43	46.86	46.28	45.71	45.14	44.57	44.00	43.43	43.42	43.41	.57143—
52.50	51.92	51.33	50.75	50.17	49.58	49	48.42	47.83	47.25	46.67	46.08	45.50	44.92	44.33	44.32	44.31	.58333+
53.57	52.98	52.38	51.78	51.19	50.59	50	49.40	48.81	48.21	47.62	47.02	46.43	45.83	45.24	45.23	45.22	.59524—
54.64	54.03	53.43	52.82	52.21	51.61	51	50.39	49.78	49.18	48.57	47.96	47.36	46.75	46.14	46.13	46.12	.60714+
55.71	55.09	54.48	53.86	53.24	52.62	52	51.38	50.76	50.14	49.52	48.90	48.28	47.67	47.05	47.04	47.03	.61905—
56.78	56.15	55.52	54.89	54.26	53.63	53	52.37	51.74	51.11	50.48	49.84	49.21	48.58	47.95	47.94	47.93	.63095+
57.86	57.21	56.57	55.93	55.28	54.64	54	53.36	52.71	52.07	51.43	50.78	50.14	49.50	48.86	48.85	48.84	.64286—
58.93	58.27	57.62	56.96	56.31	55.65	55	54.34	53.69	53.03	52.38	51.73	51.07	50.42	49.76	49.75	49.74	.65476+
59.00	58.33	57.67	57.00	56.33	55.67	56	55.33	54.67	54.00	53.33	52.67	52.00	51.33	50.67	50.66	50.65	.66667—
61.07	60.39	59.71	59.03	58.36	57.68	57	56.32	55.64	54.96	54.28	53.61	52.93	52.25	51.57	51.56	51.55	.67857+
62.14	61.45	60.76	60.07	59.38	58.69	58	57.31	56.62	55.93	55.24	54.55	53.86	53.17	52.48	52.47	52.46	.69048—
63.21	62.51	61.81	61.11	60.40	59.70	59	58.30	57.59	56.89	56.19	55.49	54.78	54.08	53.38	53.37	53.36	.70238
64.28	63.57	62.86	62.14	61.43	60.71	60	59.28	58.57	57.86	57.14	56.43	55.71	55.00	54.28	54.27	54.26	.71428+

TABLE VIII.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 16 per cent in moisture is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.															Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
65.36	64.63	63.90	63.18	62.45	61.73	61	60.27	59.55	58.82	58.09	57.37	56.64	55.92	55.19	0.72619
66.43	65.69	64.95	64.21	63.47	62.74	62	61.26	60.52	59.78	59.05	58.31	57.57	56.83	56.09	.73809+
67.50	66.75	66.00	65.25	64.50	63.75	63	62.25	61.50	60.75	60.00	59.25	58.50	57.75	57.00	.75000
68.57	67.81	67.05	66.28	65.52	64.76	64	63.24	62.47	61.71	60.95	60.19	59.43	58.67	57.90	.76190+
69.64	68.87	68.09	67.32	66.55	65.77	65	64.23	63.45	62.68	61.90	61.13	60.36	59.58	58.81	.77381—
70.71	69.93	69.14	68.36	67.57	66.78	66	65.21	64.43	63.64	62.86	62.07	61.28	60.50	59.71	.78571+
71.78	70.99	70.19	69.39	68.59	67.80	67	66.20	65.40	64.61	63.81	63.01	62.21	61.42	60.62	.79762—
72.86	72.05	71.24	70.43	69.62	68.81	68	67.19	66.38	65.57	64.76	63.95	63.14	62.33	61.52	.80952+
73.93	73.11	72.28	71.46	70.64	69.82	69	68.18	67.36	66.53	65.71	64.89	64.07	63.25	62.43	.82143—
75.00	74.17	73.33	72.50	71.67	70.83	70	69.17	68.33	67.50	66.67	65.83	65.00	64.17	63.33	.83333+
76.07	75.23	74.38	73.53	72.69	71.84	71	70.15	69.31	68.46	67.62	66.77	65.93	65.08	64.24	.84524—
77.14	76.28	75.43	74.57	73.71	72.86	72	71.14	70.28	69.43	68.57	67.71	66.86	66.00	65.14	.85714+
78.21	77.34	76.48	75.61	74.74	73.87	73	72.13	71.26	70.39	69.52	68.65	67.78	66.92	66.05	.86905—
79.28	78.40	77.52	76.64	75.76	74.88	74	73.12	72.24	71.36	70.48	69.60	68.71	67.83	66.95	.88095+
80.36	79.46	78.57	77.68	76.78	75.89	75	74.11	73.21	72.32	71.43	70.53	69.64	68.75	67.86	.89286—
81.43	80.52	79.62	78.71	77.81	76.90	76	75.09	74.19	73.28	72.38	71.48	70.57	69.67	68.76	.90476+
82.50	81.58	80.67	79.75	78.83	77.92	77	76.08	75.17	74.25	73.33	72.42	71.50	70.58	69.67	.91667—
83.57	82.64	81.71	80.78	79.86	78.93	78	77.07	76.14	75.21	74.28	73.36	72.43	71.50	70.57	.92857+
84.64	83.70	82.76	81.82	80.88	79.94	79	78.06	77.12	76.18	75.24	74.30	73.36	72.42	71.48	.94048—
85.71	84.76	83.81	82.86	81.90	80.95	80	79.05	78.09	77.14	76.19	75.24	74.28	73.33	72.38	.95238
86.78	85.82	84.86	83.89	82.93	81.96	81	80.03	79.07	78.11	77.14	76.18	75.21	74.25	73.28	.96428+
87.86	86.88	85.90	84.93	83.95	82.98	82	81.02	80.05	79.07	78.09	77.12	76.14	75.17	74.19	.97619
88.93	87.94	86.95	85.96	84.97	83.99	83	82.01	81.02	80.03	79.05	78.06	77.07	76.08	75.09	.98809+
90.00	89.00	88.00	87.00	86.00	85.00	84	83.00	82.00	81.00	80.00	79.00	78.00	77.00	76.00	1.00000
91.07	90.06	89.05	88.03	87.02	86.01	85	83.99	82.97	81.96	80.95	79.94	78.93	77.92	76.90	1.01190+
92.14	91.12	90.09	89.07	88.05	87.02	86	84.98	83.95	82.93	81.90	80.88	79.86	78.83	77.81	1.02381—
93.21	92.18	91.14	90.11	89.07	88.03	87	85.96	84.93	83.89	82.86	81.82	80.78	79.75	78.71	1.03571+
94.28	93.24	92.19	91.14	90.09	89.05	88	86.95	85.90	84.86	83.81	82.76	81.71	80.67	79.62	1.04762—
95.36	94.30	93.24	92.18	91.12	90.06	89	87.94	86.88	85.82	84.76	83.70	82.64	81.58	80.52	1.05952+
96.43	95.36	94.28	93.21	92.14	91.07	90	88.93	87.86	86.78	85.71	84.64	83.57	82.50	81.43	1.07143—
97.50	96.42	95.33	94.25	93.17	92.08	91	89.92	88.83	87.75	86.67	85.58	84.50	83.42	82.33	1.08333+
98.57	97.48	96.38	95.28	94.19	93.09	92	90.90	89.81	88.71	87.62	86.52	85.43	84.33	83.24	1.09524—
99.64	98.53	97.43	96.32	95.21	94.11	93	91.89	90.78	89.68	88.57	87.46	86.35	85.25	84.14	1.10714+
100.71	99.59	98.48	97.36	96.24	95.12	94	92.88	91.76	90.64	89.52	88.40	87.28	86.17	85.05	1.11905—
101.78	100.65	99.52	98.39	97.26	96.13	95	93.87	92.74	91.61	90.48	89.34	88.21	87.08	85.95	1.13095+
102.86	101.71	100.57	99.43	98.28	97.14	96	94.86	93.71	92.57	91.43	90.28	89.14	88.00	86.86	1.14286—
103.93	102.77	101.62	100.46	99.31	98.15	97	95.84	94.69	93.53	92.38	91.23	90.07	88.92	87.76	1.15476+
105.00	103.83	102.67	101.50	100.33	99.17	98	96.83	95.67	94.50	93.33	92.17	91.00	89.83	88.67	1.16667—
106.07	104.89	103.71	102.53	101.36	100.18	99	97.82	96.64	95.46	94.28	93.11	91.93	90.75	89.57	1.17857+
107.14	105.95	104.76	103.57	102.38	101.19	100	98.81	97.62	96.43	95.24	94.05	92.86	91.67	90.48	1.19048—
108.21	107.01	105.81	104.61	103.40	102.20	101	99.80	98.59	97.39	96.19	94.99	93.78	92.58	91.38	1.20238
109.28	108.07	106.86	105.64	104.43	103.21	102	100.78	99.57	98.36	97.14	95.93	94.71	93.50	92.28	1.21428+
110.36	109.13	107.90	106.68	105.45	104.23	103	101.77	100.55	99.32	98.09	96.87	95.64	94.42	93.19	1.22619
111.43	110.19	108.95	107.71	106.47	105.24	104	102.76	101.52	100.28	99.05	97.81	96.57	95.33	94.09	1.23809+
112.50	111.25	110.00	108.75	107.50	106.25	105	103.75	102.50	101.25	100.00	98.75	97.50	96.25	95.00	1.25000
113.57	112.31	111.05	109.78	108.52	107.26	106	104.74	103.47	102.21	100.95	99.69	98.43	97.17	95.90	1.26190+
114.64	113.37	112.09	110.82	109.55	108.27	107	105.73	104.45	103.18	101.90	100.63	99.36	98.08	96.81	1.27381—
115.71	114.43	113.14	111.86	110.57	109.28	108	106.71	105.43	104.14	102.86	101.57	100.28	98.99	97.71	1.28571+
116.78	115.48	114.19	112.89	111.59	110.30	109	107.70	106.40	105.11	103.81	102.51	101.21	99.92	98.62	1.29762—
117.86	116.55	115.24	113.93	112.62	111.31	110	108.69	107.38	106.07	104.76	103.45	102.14	100.83	99.52	1.30952+
118.93	117.61	116.28	114.96	113.64	112.32	111	109.68	108.36	107.03	105.71	104.39	103.07	101.75	100.43	1.32143—
120.00	118.67	117.33	116.00	114.67	113.33	112	110.67	109.33	108.00	106.67	105.33	104.00	102.67	101.33	1.33333+
121.07	119.73	118.38	117.03	115.69	114.34	113	111.65	110.31	108.96	107.62	106.27	104.93	103.58	102.24	1.34524—
122.14	120.78	119.43	118.07	116.71	115.36	114	112.64	111.28	109.93	108.57	107.21	105.86	104.50	103.14	1.35714+
123.21	121.84	120.48	119.11	117.74	116.37	115	113.63	112.26	110.89	109.52	108.15	106.78	105.42	104.05	1.36905—
124.28	122.90	121.52	120.14	118.76	117.38	116	114.62	113.24	111.86	110.48	109.09	107.71	106.33	104.95	1.38095+
125.36	123.96	122.57	121.18	119.78	118.39	117	115.61	114.21	112.82	111.43	110.03	108.64	107.25	105.86	1.39286—
126.43	125.02	123.62	122.21	120.81	119.40	118	116.59	115.19	113.78	112.38	110.98	109.57	108.17	106.76	1.40476+
127.50	126.08	124.67	123.25	121.83	120.42	119	117.58	116.17	114.75	113.33	111.92	110.50	109.08	107.67	1.41667—
128.57	127.14	125.71	124.28	122.86	121.43	120	118.57	117.14	115.71	114.28	112.86	111.43	110.00	108.57	1.42857+

TABLE IX.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 17 per cent in moisture is in even cents.

Moisture content (per cent) and relative value per unit of measure.																Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.	
1.08	1.07	1.06	1.05	1.04	1.02	1.01	1	0.99	0.98	0.96	0.95	0.94	0.93	.91	0.01205—	
2.17	2.14	2.12	2.10	2.07	2.05	2.02	2	1.98	1.95	1.93	1.90	1.88	1.85	1.83	.02110—	
3.25	3.22	3.18	3.14	3.11	3.07	3.03	3	2.96	2.93	2.89	2.85	2.82	2.78	2.75	.03614+	
4.34	4.29	4.24	4.19	4.14	4.10	4.05	4	3.95	3.90	3.85	3.81	3.76	3.71	3.66	.04819+	
5.42	5.36	5.30	5.24	5.18	5.12	5.06	5	4.94	4.88	4.82	4.76	4.70	4.64	4.58	.06024+	
6.51	6.43	6.36	6.29	6.22	6.14	6.07	6	5.93	5.85	5.78	5.71	5.64	5.57	5.49	.07229—	
7.59	7.51	7.42	7.34	7.25	7.17	7.08	7	6.91	6.83	6.75	6.66	6.58	6.49	6.41	.08434—	
8.67	8.58	8.48	8.38	8.29	8.19	8.09	8	7.90	7.81	7.71	7.61	7.52	7.42	7.32	.09638+	
9.76	9.65	9.54	9.43	9.32	9.22	9.11	9	8.89	8.78	8.67	8.56	8.46	8.35	8.24	.10843+	
10.84	10.72	10.60	10.48	10.36	10.24	10.12	10	9.88	9.76	9.64	9.52	9.40	9.28	9.16	.12048+	
11.93	11.79	11.66	11.53	11.40	11.26	11.13	11	10.87	10.73	10.60	10.47	10.34	10.20	10.07	.13253—	
13.01	12.87	12.72	12.58	12.43	12.29	12.14	12	11.85	11.71	11.57	11.42	11.28	11.13	10.99	.14458—	
14.10	13.94	13.78	13.63	13.47	13.31	13.16	13	12.84	12.69	12.53	12.37	12.22	12.06	11.90	.15663—	
15.18	15.01	14.84	14.67	14.50	14.34	14.17	14	13.83	13.66	13.49	13.32	13.16	12.99	12.82	.16867+	
16.26	16.08	15.90	15.72	15.54	15.36	15.18	15	14.82	14.64	14.46	14.28	14.10	13.91	13.73	.18072+	
17.35	17.16	16.96	16.77	16.58	16.38	16.19	16	15.81	15.61	15.42	15.23	15.04	14.84	14.65	.19277+	
18.43	18.23	18.02	17.82	17.61	17.41	17.20	17	16.79	16.59	16.38	16.18	15.97	15.77	15.57	.20482—	
19.52	19.30	19.08	18.87	18.65	18.43	18.22	18	17.78	17.57	17.35	17.13	16.91	16.70	16.48	.21687+	
20.60	20.37	20.14	19.91	19.69	19.46	19.23	19	18.77	18.54	18.31	18.08	17.85	17.63	17.40	.22891+	
21.69	21.44	21.20	20.96	20.72	20.48	20.24	20	19.76	19.52	19.28	19.03	18.79	18.55	18.31	.24096+	
22.77	22.52	22.26	22.01	21.76	21.50	21.25	21	20.75	20.49	20.24	19.99	19.73	19.48	19.23	.25301+	
23.85	23.59	23.32	23.06	22.79	22.53	22.26	22	21.73	21.47	21.20	20.94	20.67	20.41	20.14	.26506—	
24.94	24.66	24.38	24.11	23.83	23.55	23.28	23	22.72	22.44	22.17	21.89	21.61	21.34	21.06	.27711—	
26.02	25.73	25.45	25.16	24.87	24.58	24.29	24	23.71	23.42	23.13	22.84	22.55	22.26	21.98	.28916+	
27.11	26.81	26.50	26.20	25.90	25.60	25.30	25	24.70	24.40	24.10	23.79	23.49	23.19	22.89	.30120+	
28.19	27.88	27.57	27.25	26.94	26.63	26.31	26	25.69	25.37	25.06	24.75	24.43	24.12	23.81	.31325+	
29.28	28.95	28.63	28.30	27.97	27.65	27.32	27	26.67	26.35	26.02	25.70	25.37	25.05	24.72	.32530+	
30.36	30.02	29.69	29.35	29.01	28.67	28.34	28	27.66	27.32	26.99	26.65	26.31	25.97	25.64	.33735+	
31.45	31.10	30.75	30.40	30.05	29.70	29.35	29	28.65	28.30	27.95	27.60	27.25	26.90	26.55	.34940+	
32.53	32.17	31.81	31.44	31.08	30.72	30.36	30	29.64	29.28	28.91	28.55	28.19	27.83	27.47	.36144+	
33.61	33.24	32.87	32.49	32.12	31.75	31.37	31	30.63	30.25	29.88	29.50	29.13	28.76	28.38	.37349+	
34.70	34.31	33.93	33.54	33.16	32.77	32.38	32	31.61	31.23	30.84	30.46	30.07	29.69	29.30	.38554+	
35.78	35.38	34.99	34.59	34.19	33.79	33.40	33	32.60	32.20	31.81	31.41	31.01	30.61	30.22	.39759—	
36.87	36.46	36.05	35.64	35.23	34.82	34.41	34	33.59	33.18	32.77	32.36	31.95	31.54	31.13	.40964—	
37.95	37.53	37.11	36.69	36.26	35.84	35.42	35	34.58	34.16	33.73	33.31	32.89	32.47	32.05	.42169—	
39.03	38.60	38.17	37.73	37.30	36.87	36.43	36	35.56	35.13	34.70	34.26	33.83	33.40	32.96	.43373+	
40.12	39.67	39.23	38.78	38.34	37.89	37.44	37	36.55	36.11	35.66	35.22	34.77	34.32	33.88	.44578+	
41.20	40.75	40.29	39.83	39.37	38.91	38.46	38	37.54	37.08	36.63	36.17	35.71	35.25	34.79	.45783+	
42.29	41.82	41.35	40.88	40.41	39.94	39.47	39	38.53	38.06	37.59	37.12	36.65	36.18	35.71	.46988+	
43.37	42.89	42.41	41.93	41.44	40.96	40.48	40	39.52	39.04	38.55	38.07	37.59	37.11	36.63	.48193—	
44.46	43.96	43.47	42.97	42.48	41.99	41.49	41	40.50	40.01	39.52	39.02	38.53	38.03	37.54	.49397+	
45.54	45.03	44.53	44.02	43.52	43.01	42.50	42	41.49	40.99	40.48	39.97	39.47	38.96	38.46	.50602+	
46.63	46.11	45.59	45.07	44.55	44.03	43.52	43	42.48	41.96	41.44	40.93	40.41	39.89	39.37	.51807+	
47.71	47.18	46.65	46.12	45.59	45.06	44.53	44	43.47	42.94	42.41	41.88	41.35	40.82	40.29	.53012—	
48.79	48.25	47.71	47.17	46.63	46.08	45.54	45	44.46	43.91	43.37	42.83	42.29	41.75	41.20	.54217—	
49.88	49.32	48.77	48.22	47.66	47.11	46.55	46	45.45	44.89	44.34	43.78	43.23	42.67	42.12	.55422—	
50.96	50.40	49.83	49.26	48.70	48.13	47.56	47	46.43	45.87	45.30	44.73	44.17	43.60	43.03	.56626+	
52.05	51.47	50.89	50.31	49.73	49.16	48.58	48	47.42	46.84	46.26	45.69	45.11	44.53	43.95	.57831+	
53.13	52.54	51.95	51.36	50.77	50.18	49.59	49	48.41	47.82	47.23	46.64	46.05	45.46	44.87	.59036+	
54.22	53.61	53.01	52.41	51.81	51.20	50.60	50	49.40	48.79	48.19	47.59	46.99	46.38	45.78	.60241—	
55.30	54.69	54.07	53.46	52.84	52.23	51.61	51	50.38	49.77	49.16	48.54	47.93	47.31	46.70	.61446—	
56.38	55.76	55.13	54.51	53.88	53.25	52.63	52	51.37	50.75	50.12	49.49	48.87	48.24	47.61	.62651—	
57.47	56.83	56.19	55.55	54.91	54.28	53.64	53	52.36	51.72	51.08	50.44	49.81	49.17	48.53	.63855+	
58.55	57.90	57.25	56.60	55.95	55.30	54.65	54	53.35	52.70	52.05	51.40	50.75	50.10	49.44	.65060+	
59.64	58.97	58.31	57.65	56.99	56.32	55.66	55	54.34	53.67	53.01	52.35	51.69	51.02	50.36	.66265—	
60.72	60.05	59.37	58.70	58.02	57.35	56.67	56	55.32	54.65	53.98	53.30	52.63	51.95	51.28	.67470—	
61.81	61.12	60.43	59.75	59.06	58.37	57.69	57	56.31	55.63	54.94	54.25	53.57	52.88	52.19	.68675—	
62.89	62.19	61.49	60.79	60.09	59.39	58.70	58	57.30	56.60	55.90	55.20	54.50	53.81	53.11	.69879+	
63.97	63.26	62.55	61.84	61.13	60.42	59.71	59	58.29	57.58	56.87	56.16	55.44	54.73	54.02	.71084+	
65.06	64.34	63.61	62.89	62.17	61.44	60.72	60	59.28	58.55	57.83	57.11	56.38	55.66	54.94	.72289+	

TABLE IX.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 10 to 24 per cent in moisture when the price for a unit testing 17 per cent in moisture is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.																	Value of each 1 per cent of dry matter.
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24			
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>	
66.14	65.41	64.67	63.94	63.20	62.47	61.73	61	60.26	59.53	58.79	58.06	57.32	56.59	55.85	55.85	0.73494—	
67.23	66.48	65.73	64.99	64.24	63.49	62.75	62	61.25	60.51	59.76	59.01	58.26	57.52	56.77	56.77	.74699—	
68.31	67.55	66.79	66.04	65.28	64.52	63.76	63	62.24	61.48	60.72	59.96	59.20	58.45	57.69	57.69	.75904—	
69.40	68.63	67.87	67.05	66.31	65.54	64.77	64	63.23	62.46	61.69	60.91	60.14	59.37	58.60	58.60	.77108+	
70.48	69.70	68.91	68.13	67.35	66.57	65.78	65	64.22	63.43	62.65	61.87	61.08	60.30	59.52	59.52	.78313+	
71.57	70.77	69.97	69.18	68.38	67.59	66.79	66	65.20	64.41	63.61	62.82	62.02	61.23	60.43	60.43	.79518	
72.65	71.84	71.04	70.23	69.42	68.61	67.81	67	66.19	65.38	64.58	63.77	62.96	62.16	61.35	61.35	.80723—	
73.73	72.91	72.10	71.28	70.46	69.64	68.82	68	67.18	66.36	65.54	64.72	63.90	63.08	62.26	62.26	.81928—	
74.82	73.99	73.16	72.32	71.49	70.66	69.83	69	68.17	67.34	66.50	65.67	64.84	64.01	63.18	63.18	.83132+	
75.90	75.06	74.22	73.37	72.53	71.69	70.84	70	69.16	68.31	67.47	66.63	65.78	64.94	64.10	64.10	.84337+	
76.99	76.13	75.28	74.42	73.57	72.71	71.85	71	70.14	69.29	68.43	67.58	66.72	65.87	65.01	65.01	.85542+	
78.07	77.20	76.34	75.47	74.60	73.73	72.87	72	71.13	70.26	69.40	68.53	67.66	66.79	65.93	65.93	.86747—	
79.16	78.28	77.40	76.52	75.64	74.76	73.88	73	72.12	71.24	70.36	69.48	68.60	67.72	66.84	66.84	.87952—	
80.24	79.35	78.46	77.57	76.67	75.78	74.89	74	73.11	72.22	71.32	70.43	69.54	68.65	67.76	67.76	.89157—	
81.32	80.42	79.52	78.61	77.71	76.81	75.90	75	74.10	73.19	72.29	71.38	70.48	69.58	68.67	68.67	.90361+	
82.41	81.49	80.58	79.66	78.75	77.83	76.91	76	75.08	74.17	73.25	72.34	71.42	70.50	69.59	69.59	.91566+	
83.49	82.57	81.64	80.71	79.78	78.85	77.93	77	76.07	75.14	74.22	73.29	72.36	71.43	70.50	70.50	.92771—	
84.58	83.64	82.70	81.76	80.82	79.88	78.94	78	77.06	76.12	75.18	74.24	73.30	72.36	71.42	71.42	.93976—	
85.66	84.71	83.76	82.81	81.85	80.90	79.95	79	78.05	77.10	76.14	75.19	74.24	73.29	72.34	72.34	.95181—	
86.75	85.78	84.82	83.85	82.89	81.93	80.96	80	79.03	78.07	77.11	76.14	75.18	74.22	73.25	73.25	.96385+	
87.83	86.85	85.88	84.90	83.93	82.95	81.97	81	80.02	79.05	78.07	77.10	76.12	75.14	74.17	74.17	.97590+	
88.91	87.93	86.94	85.95	84.96	83.97	82.99	82	81.01	80.02	79.04	78.05	77.06	76.07	75.08	75.08	.98795+	
90.00	89.00	88.00	87.00	86.00	85.00	84.00	83	82.00	81.00	80.00	79.00	78.00	77.00	76.00	76.00	1.00000	
91.08	90.07	89.06	88.05	87.04	86.02	85.01	84	82.99	81.98	80.96	79.95	78.94	77.93	76.91	76.91	1.01205—	
92.17	91.14	90.12	89.10	88.07	87.05	86.02	85	83.98	82.95	81.93	80.90	79.88	78.85	77.83	77.83	1.02410—	
93.25	92.22	91.18	90.14	89.11	88.07	87.03	86	84.96	83.93	82.89	81.85	80.82	79.78	78.75	78.75	1.03614+	
94.34	93.29	92.24	91.19	90.14	89.10	88.05	87	85.95	84.90	83.85	82.81	81.76	80.71	79.66	79.66	1.04819+	
95.42	94.36	93.30	92.24	91.18	90.12	89.06	88	86.94	85.88	84.82	83.76	82.70	81.64	80.58	80.58	1.06024—	
96.51	95.43	94.36	93.29	92.22	91.14	90.07	89	87.93	86.85	85.78	84.71	83.64	82.57	81.49	81.49	1.07229—	
97.59	96.51	95.42	94.34	93.25	92.17	91.08	90	88.91	87.83	86.75	85.66	84.58	83.49	82.41	82.41	1.08434—	
98.67	97.58	96.48	95.38	94.29	93.19	92.09	91	89.90	88.81	87.71	86.61	85.52	84.42	83.32	83.32	1.09638+	
99.76	98.65	97.54	96.43	95.32	94.22	93.11	92	90.89	89.78	88.67	87.56	86.46	85.35	84.24	84.24	1.10843+	
100.84	99.72	98.60	97.48	96.36	95.24	94.12	93	91.88	90.76	89.64	88.52	87.40	86.28	85.16	85.16	1.12048+	
101.93	100.79	99.66	98.53	97.40	96.26	95.13	94	92.87	91.73	90.60	89.47	88.34	87.20	86.07	86.07	1.13253+	
103.01	101.87	100.72	99.58	98.43	97.29	96.14	95	93.85	92.71	91.57	90.42	89.28	88.13	86.99	86.99	1.14458—	
104.10	102.94	101.78	100.63	99.47	98.31	97.16	96	94.84	93.69	92.53	91.37	90.22	89.06	87.90	87.90	1.15663—	
105.18	104.01	102.84	101.67	100.50	99.34	98.17	97	95.83	94.66	93.49	92.32	91.16	89.99	88.82	88.82	1.16867+	
106.26	105.08	103.90	102.72	101.54	100.36	99.18	98	96.82	95.64	94.46	93.28	92.10	90.91	89.73	89.73	1.18072+	
107.35	106.16	104.96	103.77	102.58	101.38	100.19	99	97.81	96.61	95.42	94.23	93.04	91.84	90.65	90.65	1.19277+	
108.43	107.23	106.02	104.82	103.61	102.41	101.20	100	98.79	97.59	96.38	95.18	93.97	92.77	91.57	91.57	1.20482—	
109.52	108.30	107.08	105.87	104.65	103.43	102.22	101	99.78	98.57	97.35	96.13	94.91	93.70	92.48	92.48	1.21687—	
110.60	109.37	108.14	106.91	105.69	104.46	103.23	102	100.77	99.54	98.31	97.08	95.85	94.63	93.40	93.40	1.22891+	
111.69	110.44	109.20	107.96	106.72	105.48	104.24	103	101.76	100.52	99.28	98.03	96.79	95.55	94.31	94.31	1.24096+	
112.77	111.52	110.26	109.01	107.76	106.50	105.25	104	102.75	101.49	100.24	98.99	97.73	96.48	95.23	95.23	1.25301+	
113.85	112.59	111.32	110.06	108.79	107.53	106.26	105	103.73	102.47	101.20	99.94	98.67	97.41	96.14	96.14	1.26506+	
114.94	113.66	112.38	111.11	109.83	108.55	107.28	106	104.72	103.44	102.17	100.89	99.61	98.34	97.06	97.06	1.27711—	
116.02	114.73	113.45	112.16	110.87	109.58	108.29	107	105.71	104.42	103.13	101.84	100.55	99.26	97.98	97.98	1.28916—	
117.11	115.81	114.50	113.20	111.90	110.60	109.30	108	106.70	105.40	104.10	102.79	101.49	100.19	98.89	98.89	1.30120+	
118.19	116.88	115.57	114.25	112.94	111.63	110.31	109	107.69	106.37	105.06	103.75	102.43	101.12	99.81	99.81	1.31325+	
119.28	117.95	116.63	115.30	113.97	112.65	111.32	110	108.67	107.35	106.02	104.70	103.37	102.05	100.72	100.72	1.32530+	
120.36	119.02	117.69	116.35	115.01	113.67	112.34	111	109.66	108.32	106.99	105.65	104.31	102.97	101.64	101.64	1.33735—	
121.45	120.10	118.75	117.40	116.05	114.70	113.35	112	110.65	109.30	107.95	106.60	105.25	103.90	102.55	102.55	1.34940—	
122.53	121.17	119.81	118.44	117.08	115.72	114.36	113	111.64	110.28	108.91	107.55	106.19	104.83	103.47	103.47	1.36144+	
123.61	122.24	120.87	119.49	118.12	116.75	115.37	114	112.63	111.25	109.88	108.50	107.13	105.76	104.38	104.38	1.37349+	
124.70	123.31	121.93	120.54	119.16	117.77	116.38	115	113.61	112.23	110.84	109.46	108.07	106.69	105.30	105.30	1.38554+	
125.78	124.38	122.99	121.59	120.19	118.79	117.40	116	114.60	113.20	111.81	110.41	109.01	107.61	106.22	106.22	1.39759	
126.87	125.46	124.05	122.64	121.23	119.82	118.41	117	115.59	114.18	112.77	111.36	109.95	108.54	107.13	107.13	1.40964—	
127.95	126.53	125.11	123.69	122.26	120.84	119.42	118	116.58	115.16	113.73	112.31	110.89	109.47	108.05	108.05	1.42169—	
129.04	127.60	126.17	124.73	123.30	121.87	120.43	119	117.56	116.13	114.70	113.26	111.83	110.40	108.96	108.96	1.43373+	
130.12	128.67	127.23	125.78	124.34	122.89	121.44	120	118.55	117.11	115.66	114.22	112.77	111.32	109.88	109.88	1.44578+	

TABLE X.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20 and the difference in value for each unit testing from 12 to 24 per cent in moisture when the price for a unit testing 15½ per cent in moisture (maximum moisture allowed in No. 2 corn, U. S. grade) is in even cents.

Moisture content (per cent) and relative value per unit of measure.														Value of each 1 per cent of dry matter.
12	13	14	15	15.5	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
1.04	1.03	1.02	1.00	1	0.99	0.98	0.97	0.96	0.95	0.93	0.92	0.91	0.90	0.01183+
2.08	2.06	2.03	2.01	2	1.99	1.96	1.94	1.92	1.89	1.87	1.85	1.82	1.80	.02367+
3.12	3.09	3.05	3.02	3	2.98	2.95	2.91	2.87	2.84	2.80	2.77	2.73	2.70	.03550+
4.16	4.12	4.07	4.02	4	3.98	3.93	3.88	3.83	3.79	3.74	3.69	3.64	3.60	.04734+
5.21	5.15	5.09	5.03	5	4.97	4.91	4.85	4.79	4.73	4.67	4.61	4.56	4.50	.05917+
6.25	6.18	6.11	6.03	6	5.96	5.89	5.82	5.75	5.68	5.61	5.54	5.47	5.40	.07100+
7.29	7.21	7.12	7.04	7	6.96	6.87	6.79	6.71	6.63	6.54	6.46	6.38	6.29	.08284+
8.33	8.24	8.14	8.05	8	7.95	7.86	7.76	7.67	7.57	7.48	7.38	7.29	7.19	.09467+
9.37	9.27	9.16	9.05	9	8.95	8.84	8.73	8.63	8.52	8.41	8.31	8.20	8.09	.10651+
10.41	10.29	10.18	10.06	10	9.94	9.82	9.70	9.58	9.47	9.35	9.23	9.11	8.99	.11834+
11.45	11.32	11.19	11.06	11	10.93	10.80	10.67	10.54	10.41	10.28	10.15	10.02	9.89	.13018-
12.50	12.35	12.21	12.07	12	11.93	11.79	11.64	11.50	11.36	11.22	11.08	10.93	10.79	.14201+
13.54	13.38	13.23	13.08	13	12.92	12.77	12.61	12.46	12.31	12.15	12.00	11.85	11.69	.15385-
14.58	14.41	14.25	14.08	14	13.92	13.75	13.58	13.42	13.25	13.09	12.92	12.76	12.59	.16568
15.62	15.44	15.26	15.09	15	14.91	14.73	14.55	14.38	14.20	14.02	13.84	13.67	13.49	.17751+
16.66	16.47	16.28	16.09	16	15.90	15.72	15.53	15.34	15.15	14.96	14.77	14.58	14.39	.18935-
17.70	17.50	17.30	17.10	17	16.90	16.70	16.50	16.29	16.09	15.89	15.69	15.49	15.29	.20118+
18.74	18.53	18.32	18.11	18	17.89	17.68	17.47	17.25	17.04	16.83	16.61	16.40	16.19	.21302-
19.79	19.56	19.34	19.11	19	18.89	18.66	18.44	18.21	17.99	17.76	17.54	17.31	17.09	.22485+
20.83	20.59	20.35	20.12	20	19.88	19.64	19.41	19.17	18.93	18.70	18.46	18.22	17.99	.23669-
21.87	21.62	21.37	21.12	21	20.87	20.63	20.38	20.13	19.88	19.63	19.38	19.14	18.89	.24852
22.91	22.65	22.39	22.13	22	21.87	21.61	21.35	21.09	20.83	20.57	20.31	20.05	19.79	.26035+
23.95	23.68	23.41	23.14	23	22.86	22.59	22.32	22.05	21.77	21.50	21.23	20.96	20.69	.27219-
24.99	24.71	24.42	24.14	24	23.86	23.57	23.29	23.00	22.72	22.44	22.15	21.87	21.58	.28402+
26.03	25.74	25.44	25.15	25	24.85	24.56	24.26	23.96	23.67	23.37	23.08	22.78	22.48	.29586-
27.08	26.77	26.46	26.15	26	25.84	25.54	25.23	24.92	24.61	24.31	24.00	23.69	23.38	.30769+
28.12	27.80	27.48	27.16	27	26.84	26.52	26.20	25.88	25.56	25.24	24.92	24.60	24.28	.31953-
29.16	28.83	28.50	28.16	28	27.83	27.50	27.17	26.84	26.51	26.18	25.85	25.51	25.18	.33136
30.20	29.86	29.51	29.17	29	28.83	28.48	28.14	27.80	27.45	27.11	26.77	26.42	26.08	.34319+
31.24	30.89	30.53	30.18	30	29.82	29.47	29.11	28.76	28.40	28.05	27.69	27.34	26.98	.35503-
32.28	31.92	31.55	31.18	31	30.82	30.45	30.08	29.71	29.35	28.98	28.61	28.25	27.88	.36686+
33.32	32.95	32.57	32.19	32	31.81	31.43	31.05	30.67	30.30	29.92	29.54	29.16	28.78	.37870
34.37	33.98	33.58	33.19	33	32.80	32.41	32.02	31.63	31.24	30.85	30.46	30.07	29.68	.39053+
35.41	35.01	34.60	34.20	34	33.80	33.40	32.99	32.59	32.19	31.79	31.38	30.98	30.58	.40237-
36.45	36.03	35.62	35.21	35	34.79	34.38	33.96	33.55	33.14	32.72	32.31	31.89	31.48	.41420+
37.49	37.06	36.64	36.21	36	35.79	35.36	34.93	34.51	34.08	33.66	33.23	32.80	32.38	.42603+
38.53	38.09	37.66	37.22	37	36.78	36.34	35.90	35.47	35.03	34.59	34.15	33.71	33.28	.43787-
39.57	39.12	38.67	38.22	38	37.77	37.32	36.87	36.42	35.98	35.53	35.08	34.63	34.18	.44970+
40.61	40.15	39.69	39.23	39	38.77	38.31	37.85	37.38	36.92	36.46	36.00	35.54	35.08	.46154-
41.66	41.18	40.71	40.24	40	39.76	39.29	38.82	38.34	37.87	37.40	36.92	36.45	35.98	.47337+
42.70	42.21	41.73	41.24	41	40.76	40.27	39.79	39.30	38.82	38.33	37.85	37.36	36.87	.48521-
43.74	43.24	42.74	42.25	42	41.75	41.25	40.76	40.26	39.76	39.27	38.77	38.27	37.77	.49704+
44.78	44.27	43.76	43.25	43	42.74	42.24	41.73	41.22	40.71	40.20	39.69	39.18	38.67	.50887+
45.82	45.30	44.78	44.26	44	43.74	43.22	42.70	42.18	41.66	41.14	40.61	40.09	39.57	.52071
46.86	46.33	45.80	45.26	45	44.73	44.20	43.67	43.13	42.60	42.07	41.54	41.00	40.47	.53254+
47.90	47.36	46.82	46.27	46	45.73	45.18	44.64	44.09	43.55	43.01	42.46	41.92	41.37	.54438-
48.95	48.39	47.83	47.28	47	46.72	46.16	45.61	45.05	44.50	43.94	43.38	42.83	42.27	.55621+
49.99	49.42	48.85	48.28	48	47.72	47.15	46.58	46.01	45.44	44.87	44.31	43.74	43.17	.56805+
51.03	50.45	49.87	49.29	49	48.71	48.13	47.55	46.97	46.39	45.81	45.23	44.65	44.07	.57988+
52.07	51.48	50.89	50.30	50	49.70	49.11	48.52	47.93	47.34	46.74	46.15	45.56	44.97	.59172-
53.11	52.51	51.90	51.30	51	50.70	50.09	49.49	48.89	48.28	47.68	47.08	46.47	45.87	.60355
54.15	53.54	52.92	52.31	52	51.69	51.08	50.46	49.84	49.23	48.61	48.00	47.38	46.77	.61538+
55.19	54.57	53.94	53.31	53	52.69	52.06	51.43	50.80	50.18	49.55	48.92	48.29	47.67	.62722-
56.24	55.60	54.96	54.32	54	53.68	53.04	52.40	51.76	51.12	50.48	49.84	49.21	48.57	.63905+
57.28	56.63	55.98	55.32	55	54.67	54.02	53.37	52.72	52.07	51.42	50.77	50.12	49.47	.65089-
58.32	57.66	56.99	56.33	56	55.67	55.00	54.34	53.68	53.02	52.35	51.69	51.03	50.37	.66272+
59.36	58.69	58.01	57.34	57	56.66	55.99	55.31	54.64	53.96	53.29	52.61	51.94	51.27	.67456+
60.40	59.71	59.03	58.34	58	57.66	56.97	56.28	55.60	54.91	54.22	53.54	52.85	52.16	.68639
61.44	60.74	60.05	59.35	59	58.65	57.95	57.25	56.55	55.85	55.16	54.46	53.76	53.06	.69822+
62.48	61.77	61.06	60.35	60	59.64	58.93	58.22	57.51	56.80	56.09	55.38	54.67	53.96	.71006-

TABLE X.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20 and the difference in value for each unit testing from 12 to 24 per cent in moisture when the price for a unit testing 15½ per cent in moisture (maximum moisture allowed in No. 2 corn, U. S. grade) is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.														Value of each 1 per cent of dry matter.
12	13	14	15	15.5	16	17	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
63.53	62.80	62.08	61.36	61	60.64	59.92	59.19	58.47	57.75	57.03	56.31	55.58	54.86	0.72189+
64.57	63.83	63.10	62.37	62	61.63	60.90	60.16	59.43	58.70	57.96	57.23	56.50	55.76	.73373—
65.61	64.86	64.12	63.37	63	62.63	61.88	61.13	60.39	59.64	58.90	58.15	57.41	56.66	.74556+
66.65	65.89	65.14	64.38	64	63.62	62.86	62.11	61.35	60.59	59.83	59.08	58.32	57.56	.75740—
67.69	66.92	66.15	65.38	65	64.61	63.85	63.08	62.31	61.54	60.77	60.00	59.23	58.46	.76923
68.73	67.95	67.17	66.39	66	65.61	64.83	64.05	63.26	62.48	61.70	60.92	60.14	59.36	.78106+
69.77	68.98	68.19	67.40	67	66.60	65.81	65.02	64.22	63.43	62.64	61.85	61.05	60.26	.79290—
70.82	70.01	69.21	68.40	68	67.60	66.79	65.99	65.18	64.38	63.57	62.77	61.96	61.16	.80473+
71.86	71.04	70.22	69.41	69	68.59	67.77	66.96	66.14	65.32	64.51	63.69	62.87	62.06	.81657—
72.90	72.07	71.24	70.41	70	69.58	68.76	67.93	67.10	66.27	65.44	64.61	63.79	62.96	.82840+
73.91	73.10	72.26	71.42	71	70.58	69.74	68.90	68.06	67.22	66.38	65.54	64.70	63.86	.84024—
74.98	74.13	73.28	72.42	72	71.57	70.72	69.87	69.02	68.16	67.31	66.46	65.61	64.76	.85207+
76.02	75.16	74.29	73.43	73	72.57	71.70	70.84	69.97	69.11	68.25	67.38	66.52	65.66	.86390+
77.08	76.19	75.31	74.44	74	73.56	72.69	71.81	70.93	70.06	69.18	68.31	67.43	66.56	.87574—
78.11	77.22	76.33	75.44	75	74.55	73.67	72.78	71.89	71.00	70.12	69.23	68.34	67.45	.88757+
79.15	78.25	77.35	76.45	76	75.55	74.65	73.75	72.85	71.95	71.05	70.15	69.25	68.35	.89941—
80.19	79.28	78.37	77.47	77	76.54	75.63	74.72	73.81	72.90	71.99	71.08	70.16	69.25	.91124+
81.23	80.31	79.38	78.46	78	77.54	76.61	75.69	74.77	73.85	72.92	72.00	71.08	70.15	.92308—
82.27	81.34	80.40	79.47	79	78.53	77.60	76.66	75.73	74.79	73.86	72.92	71.99	71.05	.93491+
83.31	82.37	81.42	80.47	80	79.53	78.58	77.63	76.68	75.74	74.79	73.84	72.90	71.95	.94674+
84.35	83.40	82.44	81.48	81	80.51	79.56	78.60	77.64	76.69	75.73	74.77	73.81	72.85	.95858—
85.40	84.42	83.45	82.48	82	81.51	80.54	79.57	78.60	77.63	76.66	75.69	74.72	73.75	.97044+
86.44	85.45	84.47	83.49	83	82.51	81.53	80.54	79.56	78.58	77.60	76.61	75.63	74.65	.98225—
87.48	86.48	85.49	84.50	84	83.50	82.51	81.51	80.52	79.53	78.53	77.54	76.54	75.55	.99408+
88.52	87.51	86.51	85.50	85	84.50	83.49	82.48	81.48	80.47	79.47	78.46	77.45	76.45	1.00592—
89.56	88.54	87.53	86.51	86	85.49	84.47	83.45	82.44	81.42	80.40	79.38	78.37	77.35	1.01775+
90.60	89.57	88.54	87.51	87	86.48	85.45	84.42	83.39	82.37	81.34	80.31	79.28	78.25	1.02958+
91.64	90.60	89.56	88.52	88	87.48	86.44	85.40	84.35	83.31	82.27	81.23	80.19	79.15	1.04142
92.69	91.63	90.58	89.53	89	88.47	87.42	86.37	85.31	84.26	83.21	82.15	81.10	80.05	1.05325+
93.73	92.66	91.60	90.53	90	89.47	88.40	87.34	86.27	85.21	84.14	83.08	82.01	80.95	1.06509—
94.77	93.69	92.61	91.54	91	90.46	89.38	88.31	87.23	86.15	85.08	84.00	82.92	81.84	1.07692+
95.81	94.72	93.63	92.54	92	91.45	90.37	89.28	88.19	87.10	86.01	84.92	83.83	82.74	1.08876—
96.85	95.75	94.65	93.55	93	92.45	91.35	90.25	89.15	88.05	86.95	85.85	84.74	83.64	1.10059+
97.89	96.78	95.67	94.56	94	93.44	92.33	91.23	90.11	88.99	87.88	86.77	85.66	84.54	1.11243—
98.93	97.81	96.69	95.56	95	94.44	93.31	92.19	91.06	89.94	88.82	87.69	86.57	85.44	1.12426
99.97	98.84	97.70	96.57	96	95.43	94.29	93.16	92.02	90.89	89.75	88.61	87.48	86.34	1.13609+
101.02	99.87	98.72	97.57	97	96.43	95.28	94.13	92.98	91.83	90.69	89.54	88.39	87.24	1.14793+
102.06	100.90	99.74	98.58	98	97.42	96.26	95.10	93.94	92.78	91.62	90.46	89.30	88.14	1.15976+
103.10	101.93	100.76	99.59	99	98.41	97.24	96.07	94.90	93.73	92.56	91.38	90.21	89.04	1.17160—
104.14	102.96	101.77	100.59	100	99.41	98.22	97.04	95.86	94.67	93.49	92.31	91.12	89.94	1.18343+
105.18	103.99	102.79	101.60	101	100.40	99.21	98.01	96.82	95.62	94.43	93.23	92.03	90.81	1.19527—
106.22	105.02	103.81	102.60	102	101.40	100.19	98.98	97.77	96.57	95.36	94.15	92.95	91.74	1.20710
107.25	106.05	104.83	103.61	103	102.39	101.17	99.95	98.73	97.51	96.29	95.08	93.86	92.61	1.21893+
108.31	107.08	105.85	104.61	104	103.35	102.15	100.92	99.69	98.46	97.23	96.00	94.77	93.51	1.23077—
109.35	108.11	106.86	105.62	105	104.38	103.13	101.89	100.65	99.41	98.16	96.92	95.68	94.44	1.24260+
110.39	109.14	107.88	106.63	106	105.37	104.12	102.87	101.61	100.35	99.10	97.85	96.59	95.34	1.25444—
111.43	110.16	108.90	107.63	107	106.37	105.10	103.83	102.57	101.30	100.03	98.77	97.50	96.24	1.26627+
112.47	111.19	109.92	108.64	108	107.36	106.08	104.80	103.53	102.25	100.97	99.69	98.41	97.14	1.27811—
113.51	112.22	110.93	109.64	109	108.35	107.06	105.77	104.48	103.19	101.90	100.61	99.32	98.03	1.28994
114.55	113.25	111.95	110.65	110	109.35	108.05	106.74	105.44	104.14	102.84	101.54	100.24	98.93	1.30177+
115.60	114.28	112.97	111.66	111	110.34	109.03	107.72	106.40	105.09	103.77	102.46	101.15	99.83	1.31361—
116.64	115.31	113.99	112.66	112	111.34	110.01	108.69	107.36	106.03	104.71	103.38	102.06	100.73	1.32544+
117.68	116.34	115.01	113.67	113	112.33	111.00	109.66	108.32	106.98	105.64	104.31	102.97	101.63	1.33728—
118.72	117.37	116.02	114.67	114	113.32	111.98	110.63	109.28	107.93	106.58	105.25	103.89	102.53	1.34911+
119.76	118.40	117.04	115.68	115	114.32	112.96	111.60	110.24	108.88	107.51	106.15	104.78	103.43	1.36095—
120.80	119.43	118.06	116.69	116	115.31	113.94	112.57	111.19	109.82	108.45	107.08	105.70	104.33	1.37278+
121.84	120.46	119.08	117.69	117	116.31	114.92	113.54	112.15	110.77	109.38	108.00	106.61	105.23	1.38461+
122.89	121.49	120.09	118.70	118	117.30	115.90	114.51	113.11	111.72	110.32	108.92	107.53	106.13	1.39645—
123.93	122.52	121.11	119.70	119	118.29	116.89	115.48	114.07	112.65	111.25	109.84	108.44	107.03	1.40828+
124.97	123.55	122.13	120.71	120	119.29	117.87	116.45	115.03	113.61	112.19	110.77	109.35	107.93	1.42012—

TABLE XI.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 12 to 24 per cent in moisture when the price for a unit testing 17½ per cent in moisture (maximum moisture allowed in No. 3 corn, U. S. grade) is in even cents.

Moisture content (per cent) and relative value per unit of measure.														Value of each 1 per cent of dry matter.
12	13	14	15	16	17	17.5	18	19	20	21	22	23	24	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
1.07	1.05	1.04	1.03	1.02	1.01	1	0.99	0.98	0.97	0.96	0.94	0.93	0.92	0.01212+
2.13	2.11	2.08	2.06	2.04	2.01	2	1.99	1.96	1.94	1.91	1.89	1.87	1.84	.02424+
3.20	3.16	3.13	3.09	3.05	3.02	3	2.98	2.94	2.91	2.87	2.84	2.80	2.76	.03636+
4.27	4.22	4.17	4.12	4.07	4.02	4	3.97	3.93	3.88	3.83	3.78	3.73	3.68	.04848+
5.33	5.27	5.21	5.15	5.09	5.03	5	4.97	4.91	4.85	4.79	4.73	4.67	4.61	.06061—
6.40	6.33	6.25	6.18	6.11	6.04	6	5.96	5.89	5.82	5.74	5.67	5.60	5.53	.07273—
7.47	7.38	7.30	7.21	7.13	7.04	7	6.96	6.87	6.79	6.70	6.62	6.53	6.45	.08485—
8.53	8.44	8.34	8.24	8.14	8.05	8	7.95	7.85	7.76	7.66	7.56	7.47	7.37	.09697—
9.60	9.49	9.38	9.27	9.16	9.05	9	8.94	8.84	8.73	8.62	8.51	8.40	8.29	.10999
10.67	10.54	10.42	10.30	10.18	10.06	10	9.94	9.82	9.70	9.57	9.45	9.33	9.21	.12121+
11.73	11.60	11.47	11.33	11.20	11.07	11	10.93	10.80	10.67	10.53	10.40	10.27	10.13	.13333+
12.80	12.65	12.51	12.36	12.22	12.07	12	11.93	11.78	11.64	11.49	11.34	11.20	11.05	.14545+
13.87	13.71	13.55	13.39	13.23	13.08	13	12.92	12.76	12.60	12.45	12.29	12.13	11.97	.15757+
14.93	14.76	14.59	14.42	14.25	14.08	14	13.91	13.74	13.58	13.41	13.24	13.07	12.90	.16970—
16.00	15.82	15.64	15.45	15.27	15.09	15	14.91	14.73	14.54	14.36	14.18	14.00	13.82	.18182—
17.07	16.87	16.68	16.48	16.29	16.10	16	15.90	15.71	15.51	15.32	15.13	14.93	14.74	.19394—
18.13	17.93	17.72	17.51	17.31	17.10	17	16.90	16.69	16.48	16.28	16.07	15.87	15.66	.20606
19.20	18.98	18.76	18.54	18.33	18.11	18	17.89	17.67	17.45	17.24	17.02	16.80	16.58	.21818+
20.27	20.04	19.80	19.57	19.34	19.11	19	18.88	18.65	18.42	18.19	17.96	17.73	17.50	.23030+
21.33	21.09	20.85	20.60	20.36	20.12	20	19.88	19.64	19.39	19.15	18.91	18.67	18.42	.24242+
22.40	22.14	21.89	21.63	21.38	21.13	21	20.87	20.62	20.36	20.11	19.85	19.60	19.34	.25454+
23.47	23.20	22.93	22.67	22.40	22.13	22	21.87	21.60	21.33	21.07	20.80	20.53	20.27	.26667—
24.53	24.25	23.97	23.70	23.42	23.14	23	22.86	22.58	22.30	22.02	21.74	21.47	21.19	.27879—
25.60	25.31	25.02	24.73	24.44	24.14	24	23.85	23.56	23.27	22.98	22.69	22.40	22.11	.29091—
26.67	26.36	26.06	25.76	25.45	25.15	25	24.85	24.54	24.24	23.94	23.64	23.33	23.03	.30303
27.73	27.42	27.10	26.79	26.47	26.16	26	25.84	25.53	25.21	24.90	24.58	24.27	23.95	.31515+
28.80	28.47	28.14	27.82	27.49	27.16	27	26.84	26.51	26.18	25.85	25.53	25.20	24.87	.32727+
29.87	29.53	29.19	28.85	28.51	28.17	28	27.83	27.49	27.15	26.81	26.47	26.13	25.79	.33939+
30.93	30.58	30.23	29.88	29.53	29.17	29	28.82	28.47	28.12	27.77	27.42	27.07	26.71	.35151+
32.00	31.64	31.27	30.91	30.54	30.18	30	29.82	29.45	29.09	28.73	28.36	28.00	27.64	.36364—
33.07	32.69	32.31	31.94	31.56	31.19	31	30.81	30.44	30.06	29.68	29.31	28.93	28.56	.37576—
34.13	33.74	33.36	32.97	32.58	32.19	32	31.81	31.42	31.03	30.64	30.25	29.87	29.48	.38788—
35.20	34.80	34.40	34.00	33.60	33.20	33	32.80	32.40	32.00	31.60	31.20	30.80	30.40	.40000
36.27	35.85	35.44	35.03	34.62	34.20	34	33.79	33.38	32.97	32.56	32.14	31.73	31.32	.41212+
37.33	36.91	36.48	36.06	35.64	35.21	35	34.79	34.36	33.94	33.51	33.09	32.67	32.24	.42424+
38.40	37.96	37.53	37.09	36.65	36.22	36	35.78	35.34	34.91	34.47	34.04	33.60	33.16	.43636+
39.47	39.02	38.57	38.12	37.67	37.22	37	36.77	36.33	35.88	35.43	34.98	34.53	34.08	.44848+
40.53	40.07	39.61	39.15	38.69	38.23	38	37.77	37.31	36.85	36.39	35.93	35.47	35.00	.46060+
41.60	41.13	40.65	40.18	39.71	39.24	39	38.76	38.29	37.82	37.34	36.87	36.40	35.93	.47273—
42.67	42.18	41.70	41.21	40.73	40.24	40	39.76	39.27	38.79	38.30	37.82	37.33	36.85	.48485—
43.73	43.24	42.74	42.24	41.74	41.25	41	40.75	40.25	39.76	39.26	38.76	38.27	37.77	.49697—
44.80	44.29	43.78	43.27	42.76	42.25	42	41.74	41.24	40.73	40.22	39.71	39.20	38.69	.50909—
45.87	45.34	44.82	44.30	43.78	43.26	43	42.74	42.22	41.70	41.17	40.65	40.13	39.61	.52121+
46.93	46.40	45.87	45.33	44.80	44.27	44	43.73	43.20	42.67	42.13	41.60	41.07	40.53	.53333+
48.00	47.45	46.91	46.36	45.82	45.27	45	44.73	44.18	43.64	43.09	42.54	42.00	41.45	.54545+
49.07	48.51	48.95	47.39	46.83	46.28	46	45.72	45.16	44.60	44.05	43.49	42.93	42.37	.55757+
50.13	49.56	48.99	48.42	47.85	47.28	47	46.71	46.14	45.58	45.01	44.44	43.87	43.30	.56970—
51.20	50.62	50.04	49.45	48.87	48.29	48	47.71	47.13	46.54	45.96	45.38	44.80	44.22	.58182—
52.27	51.67	51.08	50.48	49.89	49.30	49	48.70	48.11	47.51	46.92	46.33	45.73	45.14	.59394—
53.33	52.73	52.12	51.51	50.91	50.30	50	49.70	49.09	48.48	47.88	47.27	46.67	46.06	.60606
54.40	53.78	53.16	52.54	51.93	51.31	51	50.69	50.07	49.45	48.84	48.22	47.60	46.98	.61818+
55.47	54.84	54.20	53.57	52.94	52.31	52	51.68	51.05	50.42	49.79	49.16	48.53	47.90	.63030+
56.53	55.89	55.25	54.60	53.96	53.32	53	52.68	52.04	51.39	50.75	50.11	49.47	48.82	.64242+
57.60	56.94	56.29	55.63	54.98	54.33	54	53.67	53.02	52.36	51.71	51.05	50.40	49.74	.65454+
58.67	58.00	57.33	56.67	56.00	55.33	55	54.67	54.00	53.33	52.67	52.00	51.33	50.67	.66667—
59.73	59.05	58.37	57.70	57.02	56.34	56	55.66	54.98	54.30	53.62	52.94	52.27	51.59	.67879—
60.80	60.11	59.42	58.73	58.04	57.34	57	56.65	55.96	55.27	54.58	53.89	53.20	52.51	.69091—
61.87	61.16	60.46	59.76	59.05	58.35	58	57.65	56.94	56.24	55.54	54.84	54.13	53.43	.70303
62.93	62.22	61.50	60.79	60.07	59.36	59	58.64	57.93	57.21	56.50	55.78	55.07	54.35	.71515+
64.00	63.27	62.54	61.82	61.09	60.36	60	59.64	58.91	58.18	57.45	56.73	56.00	55.27	.72727+

TABLE XI.—Comparative value, on a dry-matter basis, of grain, cottonseed, flour, etc., showing the price per unit of weight (bushel, 100 pounds, etc.), from 1 cent to \$1.20, and the difference in value for each unit testing from 12 to 24 per cent in moisture when the price for a unit testing 17½ per cent in moisture (maximum moisture allowed in No. 3 corn, U. S. grade) is in even cents—Continued.

Moisture content (per cent) and relative value per unit of measure.														Value of each 1 per cent of dry matter.
12	13	14	15	16	17	17.5	18	19	20	21	22	23	24	
<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cts.</i>	<i>Cents.</i>
65.07	64.33	63.59	62.85	62.11	61.37	61	60.63	59.89	59.15	58.41	57.67	56.93	56.19	0.73939+
66.13	65.38	64.63	63.88	63.13	62.37	62	61.62	60.87	60.12	59.37	58.62	57.87	57.11	.75151+
67.20	66.44	65.67	64.91	64.14	63.38	63	62.62	61.85	61.09	60.33	59.56	58.80	58.04	.76364+
68.27	67.49	66.71	65.94	65.16	64.39	64	63.61	62.84	62.06	61.28	60.51	59.73	58.96	.77576+
69.33	68.54	67.76	66.97	66.18	65.39	65	64.61	63.82	63.03	62.24	61.45	60.67	59.88	.78788+
70.40	69.60	68.80	68.00	67.20	66.40	66	65.60	64.80	64.00	63.20	62.40	61.60	60.80	.80000
71.47	70.65	69.84	69.03	68.22	67.40	67	66.59	65.78	64.97	64.16	63.34	62.53	61.72	.81212+
72.53	71.71	70.88	70.06	69.24	68.41	68	67.59	66.76	65.94	65.11	64.29	63.47	62.64	.82424+
73.60	72.76	71.93	71.09	70.25	69.42	69	68.58	67.74	66.91	66.07	65.24	64.40	63.56	.83636+
74.67	73.82	72.97	72.12	71.27	70.42	70	69.57	68.73	67.88	67.03	66.18	65.33	64.48	.84848+
75.73	74.87	74.01	73.15	72.29	71.43	71	70.57	69.71	68.85	67.99	67.13	66.27	65.40	.86060+
76.80	75.93	75.05	74.18	73.31	72.44	72	71.56	70.69	69.82	68.94	68.07	67.20	66.33	.87273+
77.87	76.98	76.10	75.21	74.33	73.44	73	72.56	71.67	70.79	69.90	69.02	68.13	67.25	.88485+
78.93	78.04	77.14	76.24	75.34	74.45	74	73.55	72.65	71.76	70.86	69.96	69.07	68.17	.89697+
80.00	79.09	78.18	77.27	76.36	75.45	75	74.54	73.64	72.73	71.82	70.91	70.00	69.09	.90909
81.07	80.14	79.22	78.30	77.38	76.46	76	75.54	74.62	73.70	72.77	71.85	70.93	70.01	.92121+
82.13	81.20	80.27	79.33	78.40	77.47	77	76.53	75.60	74.67	73.73	72.80	71.87	70.93	.93333+
83.20	82.25	81.31	80.36	79.42	78.47	78	77.53	76.58	75.64	74.69	73.74	72.80	71.85	.94545+
84.27	83.31	82.35	81.39	80.43	79.48	79	78.52	77.56	76.60	75.65	74.69	73.73	72.77	.95757+
85.33	84.36	83.39	82.42	81.45	80.48	80	79.51	78.54	77.58	76.61	75.64	74.67	73.70	.96970+
86.40	85.42	84.44	83.45	82.47	81.49	81	80.51	79.53	78.54	77.56	76.58	75.60	74.62	.98182+
87.47	86.47	85.48	84.48	83.49	82.50	82	81.50	80.51	79.51	78.52	77.53	76.54	75.54	.99394+
88.53	87.53	86.52	85.51	84.51	83.50	83	82.50	81.49	80.48	79.48	78.47	77.47	76.46	1.00606
89.60	88.58	87.56	86.54	85.53	84.51	84	83.49	82.47	81.45	80.44	79.42	78.40	77.38	1.01818+
90.67	89.64	88.60	87.57	86.54	85.51	85	84.48	83.45	82.42	81.39	80.36	79.33	78.30	1.03030+
91.73	90.69	89.65	88.60	87.56	86.52	86	85.48	84.44	83.39	82.35	81.31	80.27	79.22	1.04242+
92.80	91.74	90.69	89.63	88.58	87.53	87	86.47	85.42	84.36	83.31	82.25	81.20	80.14	1.05454+
93.87	92.80	91.73	90.67	89.61	88.55	88	87.47	86.40	85.33	84.27	83.20	82.13	81.07	1.06667+
94.93	93.85	92.77	91.70	90.62	89.54	89	88.46	87.38	86.30	85.22	84.14	83.07	81.99	1.07879+
96.00	94.91	93.82	92.73	91.64	90.54	90	89.45	88.36	87.27	86.18	85.09	84.00	82.91	1.09091+
97.07	95.96	94.86	93.76	92.65	91.55	91	90.45	89.34	88.24	87.14	86.04	84.93	83.83	1.10303
98.13	97.02	95.93	94.79	93.67	92.56	92	91.44	90.33	89.21	88.10	86.98	85.87	84.75	1.11515+
99.20	98.07	96.94	95.82	94.69	93.56	93	92.44	91.31	90.18	89.05	87.93	86.80	85.67	1.12727+
100.27	99.13	97.99	96.85	95.71	94.57	94	93.43	92.29	91.15	90.01	88.87	87.73	86.59	1.13939+
101.33	100.18	99.03	97.88	96.73	95.57	95	94.42	93.27	92.12	90.97	89.82	88.67	87.51	1.15151+
102.40	101.24	100.07	98.91	97.74	96.58	96	95.42	94.25	93.09	91.93	90.76	89.60	88.44	1.16364+
103.47	102.29	101.11	99.94	98.76	97.59	97	96.41	95.24	94.06	92.88	91.71	90.53	89.36	1.17576+
104.53	103.34	102.16	100.97	99.78	98.59	98	97.41	96.22	95.03	93.84	92.65	91.47	90.28	1.18788+
105.60	104.40	103.20	102.00	100.80	99.60	99	98.40	97.20	96.00	94.80	93.60	92.40	91.20	1.20000
106.67	105.45	104.24	103.03	101.82	100.60	100	99.39	98.18	96.97	95.76	94.54	93.33	92.12	1.21212+
107.73	106.51	105.28	104.06	102.84	101.61	101	100.39	99.16	97.94	96.71	95.49	94.27	93.04	1.22424+
108.80	107.56	106.33	105.09	103.85	102.62	102	101.38	100.14	98.91	97.67	96.44	95.20	93.96	1.23636+
109.87	108.62	107.37	106.12	104.87	103.63	103	102.37	101.13	99.88	98.63	97.38	96.13	94.88	1.24848+
110.93	109.67	108.41	107.15	105.89	104.63	104	103.37	102.11	100.85	99.59	98.33	97.07	95.80	1.26060+
112.00	110.73	109.45	108.18	106.91	105.64	105	104.36	103.09	101.82	100.54	99.27	98.00	96.73	1.27273+
113.07	111.78	110.50	109.21	107.93	106.64	106	105.36	104.07	102.79	101.50	100.22	98.93	97.65	1.28485+
114.13	112.84	111.55	110.24	108.94	107.65	107	106.35	105.05	103.76	102.46	101.16	99.87	98.57	1.29697+
115.20	113.89	112.58	111.27	109.96	108.65	108	107.34	106.04	104.73	103.42	102.11	100.80	99.49	1.30910+
116.27	114.94	113.62	112.30	110.98	109.66	109	108.34	107.02	105.70	104.37	103.05	101.73	100.41	1.32121+
117.33	116.00	114.67	113.33	112.00	110.67	110	109.33	108.00	106.67	105.33	104.00	102.67	101.33	1.33333+
118.40	117.05	115.71	114.36	113.02	111.67	111	110.33	108.98	107.64	106.29	104.94	103.60	102.25	1.34545+
119.47	118.11	116.75	115.39	114.03	112.68	112	111.32	109.96	108.60	107.25	105.89	104.53	103.17	1.35757+
120.53	119.16	117.79	116.42	115.05	113.68	113	112.31	110.94	109.58	108.21	106.84	105.47	104.10	1.36970+
121.60	120.22	118.84	117.45	116.07	114.69	114	113.31	111.93	110.54	109.16	107.78	106.40	105.02	1.38182+
122.67	121.27	119.88	118.48	117.09	115.70	115	114.30	112.91	111.51	110.12	108.73	107.33	105.94	1.39394+
123.73	122.33	120.92	119.51	118.11	116.70	116	115.30	113.89	112.48	111.08	109.67	108.27	106.86	1.40606
124.80	123.38	121.96	120.54	119.13	117.71	117	116.29	114.87	113.45	112.04	110.62	109.20	107.78	1.41818+
125.87	124.44	123.00	121.57	120.14	118.71	118	117.28	115.85	114.42	112.99	111.56	110.13	108.70	1.43030+
126.93	125.49	124.05	122.60	121.16	119.72	119	118.28	116.84	115.39	113.95	112.51	111.07	109.62	1.44242+
128.00	126.54	125.09	123.63	122.18	120.73	120	119.27	117.82	116.36	114.91	113.45	112.00	110.54	1.45454+

TABLE XII.—Comparative value of corn on a dry-matter basis, showing the price per unit of weight (bushel, 100 pounds, etc.), from 40 cents to \$1, and the difference in value for each unit testing the maximum moisture allowed in the six numerical grades when the price for any given grade is in even cents.

For No. 1 corn, U. S. grade.								For No. 2 corn, U. S. grade.							
Moisture content (per cent) and relative value per unit of measure.						Value of each 1 per cent of dry matter.	Cents.	Moisture content (per cent) and relative value per unit of weight.						Value of each 1 per cent of dry matter.	Cents.
14.0	15.5	17.5	19.5	21.5	23.0			14.0	15.5	17.5	19.5	21.5	23.0		
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.			Cts.	Cts.	Cts.	Cts.	Cts.	Cts.		
40	39.30	38.37	37.44	36.51	35.81	0.46512	40.71	40	39.05	38.11	37.16	36.45	35.75	0.47337+	
41	40.23	39.33	38.38	37.42	36.71	.47674+	41.73	41	40.03	39.06	38.09	37.36	36.65	.48521+	
42	41.27	40.29	39.31	38.34	37.60	.48837+	42.74	42	41.00	40.01	39.02	38.27	37.56	.49704+	
43	42.25	41.25	40.25	39.25	38.50	.50000	43.76	43	41.98	40.96	39.95	39.18	38.47	.50887+	
44	43.23	42.21	41.19	40.16	39.39	.51163+	44.78	44	42.96	41.92	40.87	40.09	39.38	.52071+	
45	44.21	43.17	42.12	41.07	40.29	.52325+	45.80	45	43.93	42.87	41.80	41.00	40.29	.53254+	
46	45.23	44.13	43.06	41.99	41.18	.53488+	46.82	46	44.91	43.82	42.73	41.92	41.21	.54138+	
47	46.18	45.09	43.99	42.90	42.08	.54651+	47.83	47	45.89	44.77	43.66	42.83	42.12	.55021+	
48	47.16	46.05	44.93	43.81	42.98	.55814+	48.85	48	46.86	45.73	44.59	43.74	43.03	.55872+	
49	48.14	47.00	45.87	44.73	43.87	.56977+	49.87	49	47.84	46.68	45.52	44.65	43.94	.56988+	
50	49.13	47.96	46.80	45.64	44.77	.58139+	50.89	50	48.82	47.63	46.45	45.56	44.85	.59172+	
51	50.11	48.92	47.74	46.55	45.66	.59302+	51.90	51	49.79	48.58	47.38	46.47	45.76	.60355+	
52	51.09	49.88	48.67	47.46	46.56	.60465+	52.92	52	50.77	49.54	48.31	47.38	46.67	.61538+	
53	52.07	50.84	49.61	48.38	47.45	.61628+	53.94	53	51.74	50.49	49.21	48.29	47.58	.62721+	
54	53.06	51.80	50.55	49.29	48.35	.62791+	54.96	54	52.72	51.44	50.16	49.21	48.50	.63905+	
55	54.04	52.76	51.48	50.20	49.24	.63953+	55.98	55	53.70	52.40	51.09	50.12	49.41	.65089+	
56	55.02	53.72	52.42	51.12	50.14	.65116+	56.99	56	54.67	53.35	52.02	51.03	50.32	.66272+	
57	56.00	54.68	53.35	52.03	51.03	.66279	58.01	57	55.65	54.30	52.95	51.91	51.20	.67456+	
58	56.99	55.65	54.29	52.91	51.93	.67442+	59.03	58	56.63	55.25	53.88	52.85	52.14	.68639	
59	57.97	56.60	55.23	53.85	52.82	.68605+	60.05	59	57.60	56.21	54.81	53.76	53.05	.69822+	
60	58.95	57.56	56.16	54.77	53.72	.69767+	61.06	60	58.58	57.16	55.74	54.67	53.96	.71006+	
61	59.94	58.52	57.10	55.68	54.62	.70930+	62.08	61	59.56	58.11	56.67	55.58	54.87	.72189+	
62	60.92	59.48	58.03	56.59	55.51	.72093+	63.10	62	60.52	59.06	57.60	56.50	55.80	.73373+	
63	61.90	60.44	58.97	57.50	56.41	.73256+	64.12	63	61.51	60.02	58.53	57.41	56.70	.74556+	
64	62.88	61.39	59.91	58.42	57.30	.74419+	65.14	64	62.48	60.97	59.45	58.32	57.61	.75740+	
65	63.87	62.35	60.84	59.33	58.20	.75581+	66.15	65	63.46	61.92	60.38	59.23	58.52	.76923	
66	64.85	63.31	61.78	60.24	59.09	.76744+	67.17	66	64.44	62.87	61.31	60.14	59.43	.78106+	
67	65.83	64.27	62.71	61.16	59.99	.77907+	68.19	67	65.41	63.83	62.24	61.05	60.34	.79289+	
68	66.81	65.23	63.65	62.07	60.88	.79070+	69.21	68	66.39	64.78	63.17	61.96	61.25	.80473+	
69	67.80	66.19	64.59	62.98	61.78	.80232+	70.22	69	67.37	65.73	64.10	62.87	62.16	.81657+	
70	68.78	67.15	65.52	63.89	62.67	.81395+	71.24	70	68.34	66.69	65.03	63.79	63.08	.82840+	
71	69.76	68.11	66.46	64.81	63.57	.82558+	72.26	71	69.32	67.64	65.96	64.70	64.00	.84024+	
72	70.74	69.07	67.39	65.72	64.46	.83721+	73.28	72	70.29	68.59	66.89	65.61	64.90	.85207+	
73	71.73	70.03	68.33	66.63	65.36	.84884+	74.29	73	71.27	69.54	67.82	66.52	65.81	.86390+	
74	72.71	70.99	69.27	67.55	66.25	.86046+	75.31	74	72.25	70.50	68.74	67.43	66.72	.87574+	
75	73.69	71.95	70.20	68.46	67.15	.87209+	76.33	75	73.22	71.45	69.67	68.34	67.63	.88757+	
76	74.67	72.91	71.14	69.37	68.05	.88372+	77.35	76	74.20	72.40	70.60	69.25	68.54	.89941+	
77	75.66	73.87	72.07	70.28	68.94	.89535+	78.37	77	75.18	73.35	71.53	70.16	69.45	.91124+	
78	76.64	74.82	73.01	71.20	69.84	.90698+	79.38	78	76.15	74.31	72.46	71.08	70.37	.92308+	
79	77.62	75.78	73.95	72.11	70.73	.91860+	80.40	79	77.13	75.26	73.39	71.99	71.28	.93491+	
80	78.60	76.74	74.88	73.02	71.63	.93023+	81.42	80	78.11	76.21	74.32	72.90	72.19	.94674+	
81	79.59	77.70	75.82	73.94	72.52	.94186+	82.44	81	79.08	77.16	75.25	73.81	73.10	.95858+	
82	80.57	78.66	76.75	74.85	73.42	.95349+	83.45	82	80.06	78.12	76.18	74.72	74.01	.97041+	
83	81.55	79.62	77.69	75.76	74.31	.96512+	84.47	83	81.03	79.07	77.11	75.63	74.92	.98225+	
84	82.53	80.58	78.63	76.67	75.21	.97674+	85.49	84	82.01	80.02	78.03	76.54	75.83	.99408+	
85	83.52	81.54	79.56	77.59	76.10	.98837+	86.51	85	82.99	80.98	78.96	77.45	76.74	1.00592+	
86	84.50	82.50	80.50	78.50	77.00	1.00000	87.53	86	83.96	81.93	79.89	78.37	77.66	1.01775+	
87	85.48	83.46	81.44	79.41	77.89	1.01163+	88.54	87	84.94	82.88	80.82	79.28	78.57	1.02958+	
88	86.46	84.42	82.37	80.32	78.79	1.02325+	89.56	88	85.92	83.83	81.75	80.19	79.48	1.04142	
89	87.45	85.38	83.31	81.24	79.68	1.03488+	90.58	89	86.89	84.79	82.68	81.10	80.39	1.05325+	
90	88.43	86.34	84.24	82.15	80.58	1.04651+	91.60	90	87.87	85.74	83.61	82.01	81.30	1.06509+	
91	89.41	87.30	85.18	83.06	81.48	1.05814+	92.61	91	88.85	86.69	84.54	82.92	82.21	1.07692+	
92	90.39	88.25	86.12	83.98	82.37	1.06977+	93.63	92	89.82	87.61	85.47	83.83	83.12	1.08876+	
93	91.38	89.21	87.05	84.89	83.27	1.08139+	94.65	93	90.80	88.60	86.40	84.74	84.03	1.10059+	
94	92.36	90.17	87.99	85.80	84.16	1.09302+	95.67	94	91.77	89.55	87.32	85.66	84.95	1.11243+	
95	93.34	91.13	88.92	86.71	85.06	1.10465+	96.69	95	92.75	90.50	88.25	86.57	85.86	1.12426	
96	94.32	92.09	89.86	87.63	85.95	1.11628+	97.70	96	93.73	91.45	89.18	87.48	86.77	1.13609+	
97	95.31	93.05	90.80	88.54	86.85	1.12791+	98.72	97	94.70	92.41	90.11	88.39	87.68	1.14793+	
98	96.29	94.01	91.73	89.45	87.74	1.13953+	99.74	98	95.68	93.36	91.04	89.30	88.59	1.15976+	
99	97.27	94.97	92.67	90.37	88.64	1.15116+	100.76	99	96.66	94.31	91.97	90.21	89.50	1.17160+	
100	98.25	95.93	93.60	91.28	89.53	1.16279	101.77	100	97.63	95.27	92.90	91.12	90.41	1.18343+	

TABLE XII.—Comparative value of corn on a dry-matter basis, showing the price per unit of weight (bushel, 100 pounds, etc.), from 40 cents to \$1, and the difference in value for each unit, testing the maximum moisture allowed in the six numerical grades, when the price for any given grade is in even cents—Continued.

For No. 3 corn, U. S. grade.							For No. 4 corn, U. S. grade.						
Moisture content (per cent) and relative value per unit of measure.						Value of each 1 per cent of dry matter.	Moisture content (per cent) and relative value per unit of measure.						Value of each 1 per cent of dry matter.
14.0	15.5	17.5	19.5	21.5	23.0		14.0	15.5	17.5	19.5	21.5	23.0	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
41.70	40.97	40	39.03	38.06	37.33	0.48485-	42.73	41.99	40.99	40	39.01	38.26	0.49689+
42.74	41.99	41	40.01	39.01	38.27	.49697-	43.80	43.04	42.02	41	39.98	39.22	.50932-
43.78	43.02	42	40.98	39.96	39.20	.50909	44.87	44.09	43.04	42	40.96	40.17	.52174-
44.82	44.04	43	41.96	40.91	40.13	.52121+	45.94	45.14	44.07	43	41.93	41.13	.53416+
45.87	45.07	44	42.93	41.87	41.07	.53333+	47.01	46.19	45.09	44	42.91	42.09	.54658+
46.91	46.09	45	43.91	42.82	42.00	.54545+	48.07	47.24	46.12	45	43.88	43.04	.55901-
47.95	47.11	46	44.88	43.77	42.93	.55757+	49.14	48.28	47.14	46	44.86	44.00	.57143-
48.99	48.14	47	45.86	44.72	43.87	.56970-	50.21	49.33	48.17	47	45.83	44.96	.58385-
50.04	49.16	48	46.84	45.67	44.80	.58182-	51.28	50.38	49.19	48	46.81	45.91	.59627+
51.08	50.19	49	47.81	46.62	45.73	.59394-	52.35	51.43	50.22	49	47.78	46.87	.60869+
52.12	51.21	50	48.79	47.57	46.67	.60606	53.42	52.48	51.24	50	48.76	47.83	.62112-
53.16	52.24	51	49.76	48.53	47.60	.61818+	54.48	53.53	52.27	51	49.73	48.78	.63354
54.20	53.26	52	50.74	49.48	48.53	.63030+	55.55	54.58	53.29	52	50.71	49.74	.64596+
55.25	54.28	53	51.71	50.43	49.47	.64242+	56.62	55.63	54.32	53	51.68	50.69	.65838+
56.29	55.31	54	52.69	51.38	50.40	.65454+	57.69	56.68	55.34	54	52.66	51.65	.67081-
57.33	56.33	55	53.67	52.33	51.33	.66667-	58.76	57.73	56.37	55	53.63	52.61	.68323-
58.37	57.36	56	54.64	53.28	52.27	.67879-	59.83	58.78	57.39	56	54.61	53.56	.69565+
59.42	58.38	57	55.62	54.24	53.20	.69091-	60.89	59.83	58.42	57	55.58	54.52	.70807+
60.46	59.41	58	56.59	55.19	54.13	.70303	61.96	60.88	59.44	58	56.56	55.48	.72050-
61.50	60.43	59	57.57	56.14	55.07	.71515+	63.03	61.93	60.46	59	57.53	56.43	.73292-
62.54	61.45	60	58.54	57.09	56.00	.72727+	64.10	62.98	61.49	60	58.51	57.39	.74534+
63.59	62.48	61	59.52	58.04	56.93	.73939+	65.17	64.03	62.51	61	59.48	58.35	.75776+
64.63	63.50	62	60.50	58.99	57.87	.75151+	66.23	65.08	63.54	62	60.46	59.30	.77019-
65.67	64.53	63	61.47	59.94	58.80	.76364-	67.30	66.13	64.56	63	61.43	60.26	.78261-
66.71	65.55	64	62.45	60.90	59.73	.77576-	68.37	67.18	65.59	64	62.41	61.22	.79503+
67.76	66.57	65	63.42	61.85	60.67	.78788-	69.44	68.23	66.61	65	63.38	62.17	.80745+
68.80	67.60	66	64.40	62.80	61.60	.80000	70.51	69.28	67.64	66	64.36	63.13	.81987+
69.84	68.62	67	65.37	63.75	62.53	.81212+	71.58	70.33	68.66	67	65.33	64.09	.83230-
70.88	69.65	68	66.35	64.70	63.47	.82424+	72.64	71.38	69.69	68	66.31	65.04	.84472
71.93	70.67	69	67.33	65.65	64.40	.83636+	73.71	72.43	70.71	69	67.28	66.00	.85714+
72.97	71.70	70	68.30	66.60	65.33	.84848+	74.78	73.48	71.74	70	68.26	66.96	.86956+
74.01	72.72	71	69.28	67.56	66.27	.86060+	75.85	74.53	72.76	71	69.23	67.91	.88199-
75.05	73.74	72	70.25	68.51	67.20	.87273-	76.92	75.58	73.79	72	70.21	68.87	.89441-
76.10	74.77	73	71.23	69.46	68.13	.88485-	77.99	76.63	74.81	73	71.19	69.83	.90683+
77.14	75.79	74	72.21	70.41	69.07	.89697-	79.05	77.68	75.84	74	72.16	70.78	.91925+
78.18	76.82	75	73.18	71.36	70.00	.90909	80.12	78.73	76.86	75	73.14	71.74	.93168-
79.22	77.84	76	74.16	72.31	70.93	.92121+	81.19	79.78	77.89	76	74.12	72.69	.94410-
80.27	78.87	77	75.13	73.27	71.87	.93333+	82.26	80.82	78.91	77	75.09	73.65	.95652+
81.31	79.89	78	76.11	74.22	72.80	.94545+	83.33	81.87	79.94	78	76.06	74.61	.96894+
82.35	80.91	79	77.08	75.17	73.73	.95757+	84.40	82.92	80.96	79	77.04	75.56	.98137-
83.39	81.94	80	78.06	76.12	74.67	.96970-	85.46	83.97	81.99	80	78.01	76.52	.99379-
84.43	82.96	81	79.04	77.07	75.60	.98182-	86.53	85.01	83.01	81	78.99	77.49	1.00621+
85.48	83.99	82	80.01	78.02	76.53	.99394-	87.60	86.07	84.04	82	79.96	78.43	1.01863+
86.52	85.01	83	80.99	78.97	77.47	1.00606	88.67	87.12	85.06	83	80.94	79.39	1.03105+
87.56	86.04	84	81.96	79.93	78.40	1.01818+	89.74	88.17	86.09	84	81.91	80.35	1.04348-
88.60	87.06	85	82.94	80.88	79.33	1.03030+	90.81	89.22	87.11	85	82.89	81.30	1.05590
89.65	88.08	86	83.91	81.83	80.27	1.04242+	91.87	90.27	88.14	86	83.86	82.26	1.06832+
90.69	89.11	87	84.89	82.78	81.20	1.05454+	92.94	91.32	89.16	87	84.84	83.22	1.08074+
91.73	90.13	88	85.87	83.73	82.13	1.06667-	94.01	92.37	90.19	88	85.81	84.17	1.09317-
92.77	91.16	89	86.84	84.68	83.07	1.07879-	95.08	93.42	91.21	89	86.79	85.13	1.10559
93.82	92.18	90	87.82	85.64	84.00	1.09091-	96.15	94.47	92.23	90	87.76	86.09	1.11801+
94.86	93.21	91	88.79	86.59	84.93	1.10303	97.22	95.52	93.26	91	88.74	87.04	1.13043+
95.90	94.23	92	89.77	87.54	85.87	1.11515+	98.28	96.57	94.28	92	89.71	88.00	1.14286-
96.94	95.25	93	90.74	88.49	86.80	1.12727+	99.35	97.62	95.31	93	90.69	88.96	1.15528-
97.99	96.28	94	91.72	89.44	87.73	1.13939+	100.42	98.67	96.33	94	91.66	89.91	1.16770+
99.03	97.30	95	92.70	90.39	88.67	1.15151+	101.49	99.72	97.36	95	92.64	90.87	1.18012+
100.07	98.33	96	93.67	91.34	89.60	1.16364	102.56	100.77	98.38	96	93.61	91.83	1.19255-
101.11	99.35	97	94.65	92.30	90.53	1.17576-	103.63	101.82	99.41	97	94.59	92.78	1.20497-
102.16	100.37	98	95.62	93.25	91.47	1.18788-	104.69	102.87	100.43	98	95.56	93.74	1.21739+
103.20	101.40	99	96.60	94.20	92.40	1.20000-	105.76	103.92	101.46	99	96.54	94.69	1.22981+
104.24	102.42	100	97.57	95.15	93.33	1.21212+	106.83	104.97	102.48	100	97.51	95.65	1.24224-

TABLE XII.—Comparative value of corn on a dry-matter basis, showing the price per unit of weight (bushel, 100 pounds, etc.), from 40 cents to \$1, and the difference in value for each unit testing the maximum moisture allowed in the six numerical grades when the price for any given grade is in even cents—Continued.

For No. 5 corn, U. S. grade.							For No. 6 corn, U. S. grade.						
Moisture content (per cent) and relative value per unit of measure.						Value of each 1 per cent of dry matter.	Moisture content (per cent) and relative value per unit of measure.						Value of each 1 per cent of dry matter.
14.0	15.5	17.5	19.5	21.5	23.0		14.0	15.5	17.5	19.5	21.5	23.0	
Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cents.
43.82	43.06	42.04	41.02	40	39.23	0.50955+	44.67	43.90	42.86	41.82	40.78	40	0.51948
44.92	44.13	43.09	42.04	41	40.22	.52229+	45.79	44.99	43.93	42.86	41.80	41	.53247—
46.01	45.21	44.14	43.07	42	41.20	.53503+	46.91	46.09	45.00	43.91	42.82	42	.54545+
47.11	46.29	45.19	44.09	43	42.18	.54777—	48.02	47.19	46.07	44.95	43.84	43	.55844+
48.20	47.36	46.24	45.12	44	43.16	.56051—	49.14	48.28	47.14	46.00	44.86	44	.57143—
49.30	48.44	47.29	46.15	45	44.14	.57325—	50.26	49.38	48.21	47.04	45.88	45	.58441+
50.39	49.51	48.34	47.17	46	45.12	.58599—	51.38	50.48	49.28	48.09	46.90	46	.59740+
51.49	50.59	49.39	48.20	47	46.10	.59872+	52.49	51.58	50.36	49.14	47.91	47	.61039—
52.58	51.67	50.45	49.22	48	47.08	.61146+	53.61	52.05	51.43	50.18	48.93	48	.62338—
53.68	52.74	51.50	50.25	49	48.06	.62420+	54.73	53.77	52.50	51.23	49.95	49	.63636+
54.78	53.82	52.55	51.27	50	49.04	.63694+	55.84	54.87	53.57	52.27	50.97	50	.64935—
55.87	54.90	53.60	52.30	51	50.02	.64968+	56.96	55.97	54.64	53.32	51.99	51	.66237—
56.97	55.97	54.65	53.32	52	51.01	.66242	58.08	57.06	55.71	54.36	53.01	52	.67532+
58.06	57.05	55.70	54.35	53	51.99	.67516—	59.19	58.16	56.78	55.41	54.03	53	.68834—
59.16	58.13	56.75	55.37	54	52.97	.68790—	60.31	59.26	57.86	56.45	55.05	54	.70130—
60.25	59.20	57.80	56.40	55	53.95	.70064—	61.43	60.36	58.93	57.50	56.07	55	.71428+
61.35	60.28	58.85	57.43	56	54.93	.71337+	62.54	61.45	60.00	58.54	57.09	56	.72727—
62.44	61.36	59.90	58.45	57	55.91	.72611+	63.66	62.55	61.07	59.59	58.11	57	.74026—
63.54	62.43	60.95	59.48	58	56.89	.73885+	64.78	63.65	62.14	60.64	59.13	58	.75325—
64.64	63.51	62.01	60.50	59	57.87	.75159+	65.90	64.75	63.21	61.68	60.15	59	.76623+
65.73	64.58	63.06	61.53	60	58.85	.76433+	67.01	65.84	64.28	62.73	61.17	60	.77922—
66.83	65.66	64.11	62.55	61	59.83	.77707—	68.13	66.94	65.36	63.77	62.19	61	.79221—
67.92	66.74	65.16	63.58	62	60.81	.78981—	69.25	68.04	66.43	64.82	63.21	62	.80519+
69.02	67.81	66.21	64.60	63	61.80	.80255—	70.36	69.14	67.52	65.86	64.23	63	.81818+
70.11	68.89	67.26	65.63	64	62.78	.81529—	71.48	70.23	68.57	66.91	65.25	64	.83117—
71.21	69.97	68.31	66.65	65	63.76	.82802+	72.60	71.33	69.64	67.95	66.27	65	.84415+
72.30	71.04	69.36	67.68	66	64.73	.84076+	73.71	72.43	70.71	69.00	67.28	66	.85714+
73.40	72.12	70.41	68.71	67	65.72	.85350+	74.83	73.52	71.78	70.04	68.30	67	.87013—
74.50	73.20	71.46	69.73	68	66.70	.86624+	75.95	74.62	72.86	71.09	69.32	68	.88312—
75.59	74.27	72.51	70.76	69	67.68	.87898—	77.06	75.72	73.93	72.14	70.34	69	.89610+
76.69	75.35	73.57	71.78	70	68.66	.89172—	78.18	76.82	75.00	73.18	71.36	70	.90909—
77.78	76.43	74.62	72.81	71	69.64	.90446—	79.30	77.91	76.07	74.23	72.38	71	.92208—
78.88	77.50	75.67	73.83	72	70.62	.91720—	80.41	79.01	77.14	75.27	73.40	72	.93506+
79.97	78.58	76.72	74.86	73	71.60	.92994—	81.53	80.11	78.21	76.32	74.42	73	.94805+
81.07	79.65	77.77	75.88	74	72.58	.94267+	82.65	81.21	79.28	77.36	75.44	74	.96104—
82.16	80.73	78.82	76.91	75	73.57	.95541+	83.77	82.30	80.36	78.41	76.46	75	.97402+
83.26	81.81	79.87	77.94	76	74.55	.96815+	84.88	83.40	81.43	79.45	77.48	76	.98701+
84.36	82.88	80.92	78.96	77	75.53	.98089+	86.00	84.50	82.50	80.50	78.50	77	1.00000
85.45	83.96	81.97	79.99	78	76.51	.99363—	87.12	85.60	83.57	81.54	79.52	78	1.01299—
86.55	85.04	83.02	81.01	79	77.49	1.00637—	88.23	86.69	84.64	82.59	80.54	79	1.02597+
87.64	86.11	84.08	82.04	80	78.47	1.01911—	89.35	87.79	85.71	83.64	81.56	80	1.03896+
88.74	87.19	85.13	83.06	81	79.45	1.03185—	90.47	88.89	86.78	84.63	82.53	81	1.05195+
89.83	88.27	86.18	84.09	82	80.43	1.04458+	91.58	89.99	87.86	85.73	83.60	82	1.06493+
90.93	89.34	87.23	85.11	83	81.41	1.05732+	92.70	91.08	88.93	86.77	84.62	83	1.07792—
92.02	90.42	88.28	86.14	84	82.39	1.07006+	93.82	92.18	90.00	87.82	85.64	84	1.09091—
93.12	91.50	89.33	87.16	85	83.37	1.08280+	94.93	93.28	91.07	88.86	86.65	85	1.10390—
94.22	92.57	90.38	88.19	86	84.36	1.09554+	96.05	94.38	92.14	89.91	87.67	86	1.11688+
95.31	93.65	91.43	89.22	87	85.34	1.10828—	97.17	95.47	93.21	90.95	88.69	87	1.12987—
96.41	94.73	92.48	90.24	88	86.32	1.12102—	98.28	96.57	94.28	92.00	89.71	88	1.14286—
97.50	95.80	93.53	91.27	89	87.30	1.13376—	99.40	97.67	95.36	93.04	90.73	89	1.15584+
98.60	96.88	94.58	92.29	90	88.28	1.14650—	100.52	98.77	96.43	94.09	91.75	90	1.16883+
99.69	97.95	95.64	93.32	91	89.26	1.15923+	101.64	99.86	97.50	95.14	92.77	91	1.18182—
100.79	99.03	96.69	94.34	92	90.24	1.17197+	102.75	100.96	98.57	96.18	93.79	92	1.19480+
101.88	100.11	97.74	95.37	93	91.22	1.18471+	103.87	102.06	99.64	97.23	94.81	93	1.20779—
102.98	101.18	98.79	96.39	94	92.20	1.19745+	104.99	103.15	100.71	98.27	95.83	94	1.22078—
104.08	102.26	99.84	97.42	95	93.18	1.21019	106.10	104.25	101.78	99.32	96.85	95	1.23377—
105.17	103.34	100.89	98.44	96	94.16	1.22293+	107.22	105.35	102.86	100.36	97.87	96	1.24675+
106.27	104.41	101.94	99.47	97	95.15	1.23567—	108.34	106.45	103.93	101.41	98.89	97	1.25974—
107.36	105.49	102.99	100.50	98	96.13	1.24841+	109.45	107.54	105.00	102.45	99.91	98	1.27273—
108.46	106.57	104.04	101.52	99	97.11	1.26115—	110.57	108.64	106.07	103.50	100.93	99	1.28571+
109.55	107.64	105.09	102.55	100	98.09	1.27388+	111.69	109.74	107.14	104.54	101.95	100	1.29870+



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DISADVANTAGES OF SELLING COTTON IN THE SEED.

By CHARLES F. CRESWELL, *Scientific Assistant.*

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INTRODUCTION.

The practice of selling cotton in the seed, while not as prevalent as in the early days of cotton production, is still preferred by many producers and constitutes an important factor in the marketing of the cotton crop.

In regions where cotton is not grown in sufficient quantities to attract regular buyers, the custom of marketing unginned cotton enables the producer to make a ready-cash sale of any amount of seed cotton that he may bring to the gin. However, in most markets, practically the only advantage accruing to the farmers, as a class, is the saving of the time of men and teams that otherwise would be spent awaiting their turns at the gins and in marketing the baled lint cotton.

¹ This investigation was planned by Wells A. Sherman, Specialist in Market Surveys, and supervised by Fred Taylor, Cotton Technologist. The ginning was done by George E. Gaus, Laboratory Aid, and the samples were graded by David C. Griffith, Investigator in Cotton Marketing, and Robert W. Murray, formerly Assistant in Cotton Marketing.

NOTE.—This bulletin should be of interest to cotton producers, ginners, and buyers generally.

On the other hand, in some primary markets there is an advantage to the producer who sells baled cotton to the local merchants, as many of them allow the full market price and sometimes a premium in order to collect accounts, to sell goods, and to gain the good will of the farmer. The producer who sells in the seed can not take advantage of such circumstances, as the merchants usually do not buy seed cotton.

The sale of unginned cotton is encouraged by many ginner, who operate in close association with the oil-mill companies.¹ The ginner in buying allows for all the uncertain elements of the business, and in making an offer, aims to secure a profit in addition to his regular ginning charge.

The ginner usually separates his seed cotton into about three grades, but without regard to variety, character, or length of staple—a practice which necessarily results in a mixture of the different grades and the different lengths of staple which are produced in a community. Sooner or later this condition will be discovered by discriminating buyers and can not fail to reflect on the local market to the detriment of the cotton producer.

This method of marketing also has a retarding influence on efforts for the improvement in varieties. It is difficult, if not impossible, for the grower to obtain from the ginner his own seed for planting; and the farmer is encouraged to improve his product with the sole object of increasing the yield of seed cotton per acre. Grade and staple are given so little consideration by the buyer of seed cotton that these qualities frequently are treated with indifference by the grower and little attention is given to improvement in the quality of the fiber. The better cotton, when sold in the seed, brings so small a premium over the lower grades that it does not warrant the extra care necessary to its production, and the grower is thus encouraged to bring to market inferior cotton which often contains an excess of trash, dirt, and moisture.

The Bureau of Crop Estimates of the United States Department of Agriculture in January, 1916, estimated, from reports of their correspondents and agents, the percentages of cotton sold in the seed in the several cotton-producing States. These percentages have been applied to the Census Bureau figures of cotton production for the growth years 1912 to 1915, inclusive, for the purpose of estimating the total number of bales sold in the seed in the several States during these years. Table I is presented to show these estimates.

¹ See Sherman, Wells A., Taylor, Fred, and Brand, Charles J.: Studies of Primary Cotton Market Conditions in Oklahoma. U. S. Department of Agriculture, Bulletin 36. 1913.

TABLE I.—*Estimated percentages of total crop and calculated number of bales of cotton sold in the seed in the several States.*

State.	Percent- age.	1915	1914	1913	1912
		<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>	<i>Bales.</i>
Virginia.....	60	10,000	15,000	15,000	15,000
North Carolina.....	11	81,000	107,000	92,000	100,000
South Carolina.....	2	23,000	31,000	28,000	24,000
Georgia.....	2	39,000	54,000	47,000	36,000
Florida.....	45	25,000	41,000	30,000	26,000
Alabama.....	4	41,000	69,000	59,000	53,000
Mississippi.....	3	28,000	37,000	38,000	30,000
Louisiana.....	4	13,000	18,000	17,000	15,000
Texas.....	6	184,000	263,000	226,000	279,000
Arkansas.....	13	103,000	130,000	135,000	100,000
Tennessee.....	40	118,000	149,000	147,000	107,000
Missouri.....	90	42,000	71,000	57,000	48,000
Oklahoma.....	37	230,000	456,000	312,000	372,000
Total.....		937,000	1,441,000	1,203,000	1,205,000
Percentage of crop.....		8.5	9.1	8.6	9.0

The high price of cotton seed during the 1915 season probably gave some stimulus to the practice of selling cotton unginned. The estimates given in Table I, therefore, are probably higher than would have been made had the cotton-seed prices been at the level ruling during recent years when production was greater. As the high percentages for 1915 have been applied to the census figures for 1912, 1913, and 1914, the estimates for these years are probably somewhat greater than the actual facts. This is especially true for 1914, when an unusually small quantity was sold in the seed, because much cotton was held by producers on account of the low prices resulting from the European war. The high percentage shown in Florida is because most of the Sea Island crop was sold in the seed. The practice of selling cotton unginned is shown to be most prevalent in regions of scanty production and in the newer cotton-producing sections.

The purpose of this bulletin is to set forth the results of an investigation which was conducted in Oklahoma during the season of 1913-14, in order to obtain reliable information as to the relative advantages and disadvantages accruing to the farmer who sells his unginned cotton directly to the ginner instead of having his product custom-ginned and marketing the seed and the baled lint cotton separately.

METHOD OF INVESTIGATION.

For the purposes of this investigation, nine representative seed-cotton markets were selected, in each of which the best man available for the work was appointed as a representative of the Department of Agriculture to obtain each week several 10-pound samples of seed cotton from loads sold by different farmers. With each sample was secured a record of the seller's name, date and place of sale, and price per hundred pounds. These samples were packed tightly into cloth

sacks and mailed to Oklahoma City, where the small sacks were packed into large mail bags and remailed to Washington, D. C. In the following spring this cotton was subjected to a humidifying process, making it approximately equal in moisture content to the average load of commercial seed cotton, after which 8 pounds of each sample were carefully weighed and ginned on a small 10-saw gin. The seed and lint were then weighed separately and the percentages of seed, lint, and trash calculated. In this way samples representing 881 loads of seed cotton were ginned and carefully graded.

This investigation was planned so that the results would reflect as accurately as possible the exact conditions prevailing in the seed-cotton markets. Every precaution was exercised to secure samples and information representative of actual conditions. It is believed that the small 10-saw gin yielded on the higher grades as good a quality of cotton, but, on the lower grades, about one-half grade below that actually produced from the same loads when handled by the modern gins of Oklahoma with their various cleaning attachments. On being discharged from the gin, the seed from these samples was run over a screen and in cleanliness was approximately equal to the average Oklahoma outturn. After ginning, 5 ounces of lint were taken as representative of each load of seed cotton and graded according to the Official Cotton Grades¹ formerly issued by this department.

While these results will show probably a slightly poorer quality of cotton in the lower grades than was obtained by the ginner from the actual loads, all of the samples were ginned with the same equipment, weighed on the same scales, and subjected to the same treatment throughout, and therefore they should furnish comparable data. The poorer quality of lint obtained by the use of the small gin tends to make conservative the comparisons, which are drawn later in this bulletin, between prices paid for lint and prices paid for seed cotton.

OUTTURNS FROM SEED COTTON AT GINS.

When seed cotton reaches the gin it contains varying proportions of lint, seed, and trash.² The proportions of lint and seed depend on the variety planted, the soil, and the climatic and cultural conditions under which the cotton is grown. The trash varies in amount with climatic conditions and the care with which the cotton is picked and handled. The process of ginning separates the seed cotton into its three parts—lint, seed, and trash. Some of the trash, however, always remains in both the lint and the seed.

Table II shows the number of samples of each grade obtained from 795 samples of seed cotton representing as many loads. Eighty-

¹ These grades were superseded on Dec. 15, 1914, by the Official Cotton Standards of the United States.

² The word "trash," as used throughout this bulletin, includes all foreign matter, such as leaf, hulls, dirt, etc.

six samples, which were classed as "sandy" or "dusty," have been omitted from this table, but all other samples collected have been included. The percentages of lint, seed, and trash shown are the average results from the samples yielding each grade. In commercial practice, the reported lint outturn includes an increased weight on account of bagging and ties. Therefore, these lint percentages have been increased proportionately to make due allowance for such gain in weight.

TABLE II.—Average percentages, according to grade, of lint, seed, and trash found in seed cotton.

Grade.	Number of loads sampled.	Percentages of—		
		Lint. ¹	Seed.	Trash.
Below Good Ordinary.....	41	30.38	62.78	8.18
Good Ordinary.....	47	30.86	63.51	6.99
Strict Good Ordinary.....	81	31.40	64.69	5.29
Low Middling.....	138	31.53	65.13	4.73
Strict Low Middling.....	195	31.55	65.02	4.82
Middling.....	156	32.03	65.65	3.73
Strict Middling.....	75	31.67	66.22	3.50
Good Middling.....	49	31.34	67.16	2.88
Strict Good Middling.....	13	31.20	66.94	3.23
Summary.....	795	31.52	65.20	4.67

¹ In this and following tables, the percentages include the actual lint outturn plus an allowance for bagging and ties.

The average lint outturn of these 795 samples is shown as 31.52 per cent and the average of the 881 samples collected, including those classed as "dusty" or "sandy," was found to be 31.48 per cent. The average seed and trash outturns from the 795 samples in Table II are shown as 65.20 per cent and 4.67 per cent, respectively, and the averages of the 881 samples were 64.7 per cent and 5.2 per cent, respectively. The commercial outturn was reported on 38 of these samples from Coyle, Okla., and averaged 31.79 per cent, as against the 10-saw gin outturn of 31.52 per cent from the same samples. It may be concluded, therefore, that the average lint outturn, including tare during the 1913-14 season for the districts in Oklahoma covered by this survey, was approximately 31.5 per cent.

As the trash content is one of the determining factors in judging the value of lint cotton, it will be seen that the percentages of trash as given do not fully cover the trash content of the seed cotton, for much trash remains in the lint in the lower grades, the amount gradually decreasing until, in the higher grades, comparatively little is found. Therefore, it is evident that as the grade improves, the proportions of lint and seed increase and the proportion of trash decreases.

From Table III it is apparent that the lint, seed, and trash contents of seed cotton have wide extremes in each of the different

markets. The minimum ranges in lint percentages shown are for the markets from which a comparatively small number of samples were collected. If a large number of samples had been obtained in all markets, it is evident that the range of variation would have been found to be even greater than here given.

TABLE III.—*Extreme variations in lint, seed, and trash percentages from samples obtained in specified towns in Oklahoma.*

Market.	Number of loads sampled.	Lint percentage.			Seed percentage.			Trash percentage.		
		High.	Low.	Range of variation.	High.	Low.	Range of variation.	High.	Low.	Range of variation.
		<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>	<i>P. cent.</i>
Anadarko.....	21	33.9	27.3	6.6	66.5	51.9	14.6	21.9	3.0	18.9
Coyle.....	38	36.2	29.6	6.6	70.6	53.8	16.8	15.7	.9	14.8
Crescent.....	85	38.3	27.0	11.3	69.5	52.3	17.2	20.6	.2	20.4
Crowder.....	55	38.6	27.2	11.4	66.9	58.3	8.6	11.9	.4	11.5
Haskell.....	119	36.4	25.7	10.7	71.4	61.2	10.2	14.2	.9	13.3
Kingfisher.....	143	36.3	24.3	12.0	72.3	48.1	24.2	23.2	.7	22.5
Shawnee.....	202	38.4	25.1	13.3	71.9	52.8	19.1	17.0	.8	16.2
Tahlequah.....	100	37.0	26.5	10.5	69.7	44.8	24.9	25.4	.9	24.5
Wleetka.....	118	37.4	29.4	8.0	70.2	58.6	11.6	10.9	1.1	9.8
Oklahoma.....	881	38.6	24.3	14.3	72.3	44.8	27.5	25.4	.2	25.2

CONVERSION OF SEED-COTTON PRICE TO THE EQUIVALENT LINT-COTTON PRICE.

For the purpose of making a comparison between the prices obtained for the lint content of the different loads and a further comparison of the prices for seed cotton with prices obtained for lint, the price paid for seed cotton has been converted into its equivalent price per pound of baled lint cotton. The method of determining this price may be illustrated thus:

On September 13, 1913, a load of seed cotton was sold in Shawnee at \$4 per 100 pounds, the outturns of which were 30 per cent lint, 68 per cent seed, and 2 per cent trash. Allowing the prevailing price of \$20 per ton or 1 cent per pound for the seed, the 30 pounds of lint in each hundred pounds of seed cotton brought \$4, less the value of the seed, 68 cents, or \$3.32. As it requires about 22 pounds of bagging and ties to cover 478 pounds of lint, 0.046 of a pound of bagging and ties is required to wrap each pound of cotton, and it would take 1.38 pounds of tare to bale these 30 pounds of lint. This tare would bring the same price as the lint, making the selling weight of lint and tare equal to 31.38 pounds. The ginning and baling charge of \$3.50 per bale, or 70 cents per hundred pounds, is figured on the gross weight. The 31.38 pounds gross weight of cotton would cost for ginning and baling at the rate of 70 cents per hundred pounds, or 22 cents, which added to \$3.32, the original cost of the 30 pounds of lint, gives \$3.54 as the total cost to the ginner of 31.38 pounds of baled lint, or 11.28 cents per pound. Therefore, in this particular

case, it may be considered that the ginner paid to the farmer for the cotton an equivalent of 11.28 cents per pound for the bale. Such prices are hereafter referred to as the "equivalent lint prices."

ELEMENTS THAT DETERMINE THE PRICE OF SEED COTTON.

The wide variations in the percentages of seed, lint, and trash as brought out by Table III and the inability of the ginner or producer to determine accurately these proportions or the quality of the lint or seed before the cotton is ginned, make it impossible for the ginner to figure a just price to be paid for each load, and the best he can do under the circumstances is to consider the current lint and seed prices and to take the average lint, seed, and trash contents of his community as a basis for reaching the price to be paid for the unginned cotton. This condition has resulted in dealing on a system of averages, and the ginner often determines on a certain price which he offers for all seed cotton with little regard for quality. However, if a superficial examination of the load shows it to be much worse than the average in trash or moisture content, a lower price is offered. In fixing this price the buyer is naturally careful to guard against any losses that may be incurred on account of the uncertainties involved and to figure safely his own profit. An examination of the records shows many cases where, in the same market, on the same day, the same price per hundred pounds was paid for all unginned cotton, with apparently an utter disregard for quality, the ginner apparently expecting to overcome any losses on the poorer loads by gains on the better ones. In nearly all collections of samples made during this survey the range in price paid for seed cotton on any one day was comparatively small, and many instances are shown where the load containing the best lint sold for a lower comparative price than did the load which yielded the poorest lint.

Tables IV and V are presented to bring out inconsistencies with respect to quality between equivalent lint prices resulting from a fixed seed-cotton price in a given market. Detailed statements are given of two collections of samples of seed cotton, each load of which was grown and sold by a different producer. The cotton in the first lot, represented by Table IV, was sold at \$4.50 per 100 pounds, in Tahlequah, on October 2, and each load of the second lot, represented by Table V, at \$4 per 100 pounds, in Anadarko, on November 10, 1913.

In Table IV, the quality ranges from Strict Low Middling light tinged to Good Middling; the lint outturn varies 6.8 per cent; the seed outturn, 6.4 per cent; the trash outturn, 2.1 per cent; and the equivalent lint price, 2.14 cents per pound; yet each of these 10 loads brought the producers \$4.50 per 100 pounds. In Table V, the quality ranges from below Good Ordinary to Strict Low Middling;

the lint outturn varies 4.4 per cent; the seed outturn, 11.6 per cent; the trash outturn, 12.9 per cent; and the equivalent lint price, 1.64 cents per pound; yet these loads brought uniformly \$4 per 100 pounds.

INCONSISTENCIES IN THE EQUIVALENT LINT PRICES¹ RESULTING FROM A FIXED SEED-COTTON PRICE.

TABLE IV.—Seed cotton sold at \$4.50 per 100 pounds on Oct. 2, 1913.²

Grade.	Percentage of—			Equivalent lint price per pound.
	Lint.	Seed.	Trash.	
One load of—	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Cents.</i>
S. L. M. light tinged.....	31.0	67.2	3.2	13.07
L. M.....	30.6	68.4	2.3	13.15
L. M.....	31.8	66.4	3.2	12.76
S. L. M.....	32.3	66.4	2.7	12.57
S. L. M.....	30.2	69.7	1.4	13.28
S. L. M.....	34.5	65.6	1.4	11.84
M.....	37.0	63.3	1.3	11.14
M.....	32.7	67.6	1.1	12.38
S. M.....	34.5	65.8	1.2	11.83
G. M.....	32.4	67.0	2.0	12.51

TABLE V.—Seed cotton sold at \$4 per 100 pounds on Nov. 10, 1913.²

Grade.	Percentage of—			Equivalent lint price per pound.
	Lint.	Seed.	Trash.	
One load of—	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Cents.</i>
O.....	29.2	56.3	15.8	12.48
S. G. O.....	30.4	66.5	4.4	11.66
S. G. O.....	29.6	54.9	16.8	12.36
L. M.....	30.6	59.3	11.4	11.82
L. M.....	33.1	58.7	9.7	11.03
S. L. M. spotted.....	32.5	60.5	8.4	11.14
S. L. M. spotted.....	32.3	63.5	5.6	11.11
S. L. M. spotted.....	32.4	65.1	3.9	11.03
S. L. M.....	33.6	59.6	8.3	10.84
S. L. M.....	33.1	62.7	5.7	10.90

¹ For the method of determining "equivalent lint prices" see page 6.

² In these and following tables the initials of the different grades have been used. See Table II for full-grade terms. "O," meaning Ordinary, has been used to denote cotton which was below Good Ordinary in quality.

A mere glance at these tables will show that wide variations in qualities and outturns of seed cotton exist in the same market on the same day. These variations result in marked inconsistencies in equivalent lint prices when a uniform price is paid for seed cotton regardless of its quality. In Table IV, a Strict Low Middling and a Low Middling brought the two highest equivalent lint prices and a Middling and a Strict Middling brought the two lowest prices, while a Good Middling, the best bale, brought just above the average. In Table V, the seed cotton producing the lowest grade and lowest lint outturn brought for its lint content more per pound than any other load, while the two best loads brought the two lowest equivalent lint prices. The load which produced a bale below Good Ordinary in grade brought an equivalent of 12.48 cents and the Strict Low Middling 10.84 cents, a difference of 1.64 cents per pound,

or \$8.20 per bale. According to New Orleans spot quotations on that day, the Strict Low Middling bale was worth 2.44 cents per pound more than the other bale, but brought 1.64 cents less, making a total discrepancy of 4.08 cents per pound, or \$20.40 per bale.

Since only 10 loads were sampled in each of these collections, it is unlikely that the widest ranges of grades, outturns, or equivalent lint prices which actually occurred are disclosed by the tables presented. Gross injustices can be expected in any market at any time when the same price is paid for practically all unginned cotton regardless of its quality and its percentages of seed, lint, and trash. The custom of averaging seed-cotton prices results in undue hardships on farmers who market carefully handled cotton from varieties producing superior lint and in many cases results in a direct premium to farmers who sell inferior seed cotton.

VARIATIONS IN PRICES OF IDENTICAL GRADE OF LINT COTTON WHEN SOLD UNGINNED.

The custom of selling seed cotton resulted in wide variations between the prices received for the same quality of lint cotton in the same market during the same week, and Table VI has been prepared to show these differences. Such loads as produced below Good Ordinary, sandy, or dusty cotton have been excluded, but the comparisons include all grades and all of the localities from which seed-cotton samples were obtained. Only such variations as exceeded \$10 per 500-pound bale have been given.

TABLE VI.—*Difference in prices paid for lint of a given grade when sold in the seed in the same market during the same week.*

Market.	Grade.	Week ending—	Number of loads.	Equivalent lint price per pound.			Estimated difference in price between bales.
				Highest.	Lowest.	Difference.	
				<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	
Kingfisher.....	G. O.....	Nov. 22	2	9.65	4.44	5.21	\$26.05
Shawnee.....	G. O.....	Nov. 1	5	11.53	8.71	2.82	14.10
Tahlequah.....	G. O.....	Dec. 27	3	9.32	4.98	4.34	21.70
Weleetka.....	G. O.....	Dec. 20	2	7.41	5.18	2.23	11.15
Do.....	G. O.....	Jan. 17	3	7.71	5.19	2.52	12.60
Anadarko.....	L. M.....	Nov. 22	4	11.49	7.76	3.73	18.65
Kingfisher.....	L. M.....	Nov. 1	2	10.70	8.56	2.14	10.70
Shawnee.....	L. M.....	Dec. 6	2	8.93	4.44	4.49	22.45
Crowder.....	L. M. spotted.	Dec. 27	3	11.28	7.91	3.37	16.85
Crescent.....	S. L. M.....	Oct. 25	5	13.23	10.15	3.08	15.40
Crowder.....	S. L. M.....	Dec. 6	2	11.72	9.28	2.44	12.20
Haskell.....	S. L. M.....	Nov. 15	4	14.47	12.22	2.25	11.25
Kingfisher.....	S. L. M.....	Oct. 25	4	11.05	8.89	2.16	10.80
Shawnee.....	S. L. M.....	Oct. 11	3	11.27	8.18	3.09	15.45
Crowder.....	S. L. M. spotted	Dec. 13	3	10.08	8.05	2.03	10.15
Kingfisher.....	M.....	Oct. 11	3	13.55	11.31	2.24	11.20
Weleetka.....	M.....	Nov. 15	3	10.95	8.79	2.16	10.80
Kingfisher.....	S. M.....	Oct. 11	7	15.56	10.61	4.95	24.75
Do.....	S. M.....	Oct. 18	5	11.07	9.01	2.06	10.30
Shawnee.....	S. M.....	Sept. 13	9	14.18	10.82	3.36	16.80
Do.....	S. M.....	Oct. 4	2	12.76	10.69	2.07	10.35
Do.....	S. M.....	Oct. 25	2	12.68	10.34	2.34	11.70
Do.....	G. M.....	Sept. 13	7	12.75	10.57	2.18	10.90
Do.....	G. M.....	Sept. 20	6	12.72	8.65	4.07	20.35
Kingfisher.....	S. G. M.....	Oct. 18	2	11.59	9.49	2.10	10.50

These data furnish comparisons between loads of seed cotton yielding identical quality of lint, which were sold in the same market during the same week. One comparison showed a price variation between bales of \$26.05; 4 showed variations of from \$20 to \$25; 5 from \$15 to \$20; and 15 from \$10 to \$15. The maximum variation shown is 5.21 cents per pound between two Good Ordinary loads sold in Kingfisher during the week of November 22. By comparing the price of 9.65 cents obtained for one bale with the port quotations for this grade, and allowing for freight and other charges incident to delivery, it appears that even the higher priced bale was not overvalued. It follows, therefore, that the seller of the lower priced bale received for the lint content of his load at least \$26.05 less than was his just due according to spot quotations at New Orleans.

When it is considered that this survey extended over a period of nearly 4½ months and covered 9 different markets, but that an aggregate of only 881 loads was sampled and that the maximum collection in any one market per week was only 20 samples, it is apparent that but a small number of samples would fall on the same grade during the same week in the same market. In Table VI only 4 cases are shown where the number of comparable bales is more than 5. It may be assumed, therefore, that these samples in most cases do not represent the widest variations in the seed-cotton markets, and that in many instances the variations in equivalent lint prices exceed \$10 per load for seed cotton containing lint of equal commercial value.

PRICES RECEIVED FOR THE LOWEST AND HIGHEST GRADE BALES IN THE SAME MARKET DURING THE SAME WEEK.

In 40 of the 84 collections made during this survey, the load containing the bale of lowest quality brought more for its lint content than did the load containing the bale of highest quality. Table VII is presented to bring out these 40 comparisons. The number of loads sampled and the lowest and highest grade bales produced from the loads of each collection, with their respective equivalent lint prices, are shown.

Table VII shows that in Anadarko a bale below Good Ordinary in grade brought 12.48 cents against 10.87 cents for a Strict Low Middling bale. In Coyle, two Low Middling bales averaged 13.73 cents against a Strict Good Middling 12.69 cents. In Crescent, a bale below Good Ordinary brought 9 cents against a Strict Low Middling one at 8.57 cents. In Crowder, a Good Ordinary bale brought 12.16 cents, while a Low Middling spotted bale brought 10.50 cents per pound.

TABLE VII.—Comparisons between prices paid for the lowest and highest grade loads in the same market during the same week.

Market.	Week ending—	Number of loads sampled.	Lowest grade bale.		Highest grade bale.	
			Grade.	Equivalent lint price per pound.	Grade.	Equivalent lint price per pound.
				<i>Cents.</i>		<i>Cents.</i>
Anadarko.....	Nov. 15	10	O.....	12.48	S. L. M. ¹	10.87
Do.....	Nov. 22	11	S. L. M. sandy ¹	11.05	M.....	9.38
Coyle.....	Oct. 4	20	L. M. ¹	13.73	S. G. M.....	12.69
Crescent.....	Nov. 8	3	L. M. sandy.....	11.81	M. spotted.....	11.24
Do.....	Nov. 29	11	O.....	9.00	S. L. M.....	8.57
Crowder.....	do.....	3	G. O.....	12.16	L. M. spotted.....	10.50
Do.....	Dec. 20	9	S. G. O.....	9.40	S. M. blue.....	8.29
Haskell.....	Sept. 20	9	S. L. M. ¹	13.13	S. M. ¹	12.68
Do.....	Sept. 27	10	L. M.....	13.20	G. M. ¹	13.19
Do.....	Oct. 4	11	S. G. O.....	13.20	S. G. M.....	12.54
Do.....	Oct. 11	8	S. G. O. ¹	13.72	S. M. ¹	12.85
Do.....	Oct. 18	10	G. O.....	13.31	S. M.....	12.84
Do.....	Nov. 8	9	O.....	13.48	G. M. light tinged.....	11.84
Do.....	Nov. 29	10	G. O.....	11.09	M.....	9.48
Do.....	Dec. 6	8	O. ¹	12.03	S. M.....	10.33
Do.....	Dec. 13	6	S. G. O. dusty.....	8.34	G. M. light tinged.....	5.86
Kingfisher.....	Sept. 20	5	M. sandy.....	11.85	G. M.....	11.14
Do.....	Sept. 27	6	S. L. M.....	12.44	G. M.....	11.49
Do.....	Oct. 11	19	S. G. O.....	13.38	S. G. M. ¹	12.89
Do.....	Oct. 25	14	S. L. M. ¹	10.10	S. M.....	10.05
Do.....	Nov. 1	14	O.....	11.49	S. M.....	10.59
Do.....	Nov. 8	11	O.....	10.10	S. G. M.....	9.62
Do.....	Nov. 22	9	O.....	8.52	S. M.....	7.75
Do.....	Dec. 6	8	O.....	8.37	G. M. ¹	8.02
Shawnee.....	Sept. 13	20	M.....	11.28	S. G. M. ¹	10.56
Do.....	Sept. 27	11	L. M. ¹	12.53	G. M. ¹	11.91
Do.....	Oct. 25	20	O. ¹	10.64	G. M.....	10.45
Tahlequah.....	Nov. 22	10	S. G. O. ¹	9.18	S. L. M. off colored ¹	8.71
Do.....	Oct. 4	10	L. M. ¹	12.96	G. M.....	12.51
Do.....	Oct. 25	9	S. G. O.....	13.96	M. ¹	10.84
Do.....	Nov. 1	10	S. G. O. dusty.....	12.53	S. L. M. spotted.....	11.86
Do.....	Nov. 15	10	G. O.....	11.21	M. ¹	11.01
Do.....	Nov. 22	10	S. G. O. ¹	10.58	G. M. spotted.....	9.89
Do.....	Dec. 13	11	O.....	9.10	M.....	7.85
Do.....	Dec. 20	9	O.....	7.03	S. L. M. spotted.....	6.38
Do.....	Jan. 3	6	O. ¹	6.87	L. M.....	5.81
Weleetka.....	Nov. 1	19	S. G. O. ¹	11.44	G. M.....	10.13
Do.....	Nov. 15	13	S. G. O. ¹	9.79	G. M. spotted.....	9.78
Do.....	Dec. 27	6	O. ¹	4.49	S. G. O. ¹	3.94
Do.....	Jan. 17	9	O. ¹	5.68	S. L. M. spotted.....	4.97

¹ Average equivalent lint price of 2 or more bales of the same grade is given.

Of 13 comparisons made in Haskell, 9 are shown where the lowest quality bale brought a higher price than the highest quality bale. A Strict Good Ordinary brought 13.20 cents, while a Strict Good Middling brought 12.54 cents; and two bales below Good Ordinary averaged 12.03 cents against one grading Strict Middling at 10.33 cents per pound.

In Kingfisher, 13 comparisons showed 8 cases where the lowest quality bale brought a higher price than the highest quality bale. A Strict Good Ordinary brought 13.38 cents, while two Strict Good Middling bales averaged 12.89 cents; and a bale below Good Ordinary in grade brought 10.10 cents, against a Strict Good Middling at 9.62 cents per pound.

In Tahlequah, 11 collections were made, 8 of which showed the lowest grade bale had sold for more than the highest bale. A Strict Good Ordinary brought 13.96 cents against two Middling bales which

averaged 10.84 cents; and a bale below Good Ordinary 9.10 cents against a Middling 7.85 cents per pound.

Of 12 comparisons made in Weleetka, 4 showed the poorest bale to have brought more per pound than did the best bale. Two Strict Good Ordinary bales averaged 11.44 cents, against a Good Middling 10.13 cents per pound.

A further analysis of the data concerning these 84 collections showed that in 29 comparisons the lowest equivalent lint price represented a bale of higher quality than the one actually selling at the highest price, and in 14 additional cases the quality of the bales represented by the lowest and highest prices was identical.

It is quite evident from these facts that the selling of unginned cotton in actual practice is attended by great uncertainty and frequently with much injustice to those who produce the higher grades of cotton.

IRREGULARITIES IN PRICES RECEIVED FOR THE LINT CONTENT OF SEED COTTON.

Table VIII is presented to show with respect to grade the inconsistencies between equivalent lint prices of cotton sold unginned in the same market during the same week. Only such comparisons are included in this table as show discrepancies in price over \$15 per bale.

This investigation afforded data from which 84 comparisons could be made between loads sold during the same week in the same market. The extreme discrepancies in price in 34 cases were more than \$15 per bale; in 32 cases were from \$10 to \$15; and in 18 instances were under \$10. In these comparisons ranges from 95 cents to \$30.35 per bale occurred. The widest variation occurred in Haskell during the week of November 8, when, of 9 loads sampled, a bale below Good Ordinary brought an equivalent of 13.48 cents, while a Strict Good Ordinary brought an equivalent of only 9.29 cents per pound. The lower grade bale brought 4.19 cents more per pound, while it was worth 1.88 cents per pound less, making a total discrepancy of 6.07 cents per pound or \$30.35 between the bales. The least variation found was 95 cents per bale in Crescent on November 8, when only 2 loads were sampled.

The most noteworthy facts brought out by this table are the wide discrepancies that occurred between the amounts secured by different farmers for loads of seed cotton, the frequency with which low-grade bales sold for more than did higher grades, and the wide variations between prices.

TABLE VIII.—Comparison between the lowest and highest prices, quality considered, paid in the same market within the same week for cotton when sold in the seed, showing variations per pound and per bale.

Market.	Dates of sale.	Number of loads sampled.	Grade of highest priced bale.	Highest price per pound.	Grade of lowest priced bale.	Lowest price per pound.	Actual difference paid per pound. ¹	Difference in value per pound. ¹	Total or net discrepancy in price per bale.	Estimated discrepancy in price per bale.
Anadarko.	Nov. 10.....	10	O.....	Cents. 12.48	S. L. M.....	Cents. 10.84	1.64	2.44	4.08	\$20.40
Do.	Nov. 17 ² , 18.....	11	L. M.....	11.49	L. M.....	7.76	3.73	.....	4.08	18.65
Crescent.	Oct. 21 ² , 24.....	15	S. G. M.....	14.41	S. L. M.....	10.15	4.26	.....	3.73	13.75
Do.	Dec. 10 ² , 11.....	10	S. G. O.....	8.27	G. O.....	5.12	3.15	1.81	3.45	17.25
Crowder.	Dec. 27.....	6	L. M. spotted	11.28	L. M.....	7.77	3.51	1.03	4.78	23.90
Do.	Jan. 19.....	6	S. G. O.....	9.21	L. M. light stained	5.65	3.56	.....	3.89	19.45
Haskell.	Oct. 13, 14 ²	10	G. O.....	13.31	L. M.....	11.40	1.91	1.25	3.16	16.85
Do.	Nov. 4, 5 ²	9	S. G. O.....	13.48	S. G. O.....	9.29	4.19	1.88	6.07	15.80
Do.	Nov. 24.....	10	S. L. M. spotted	13.15	S. G. O.....	8.31	4.84	.....	3.16	30.35
Do.	Dec. 2 ² , 3.....	8	S. L. M.....	12.56	S. M.....	10.33	2.23	3.19	5.42	27.10
Do.	Dec. 10 ² , 13.....	6	S. L. M. spotted	10.71	G. M. light tinged	5.86	4.85	.....	5.35	26.75
Kingfisher.	Oct. 6 ² , 11.....	19	S. M.....	15.56	S. M.....	10.61	4.95	.....	4.70	23.50
Do.	Nov. 20 ² , 22.....	9	G. O.....	9.65	G. O.....	4.44	5.21	.....	5.15	25.75
Do.	Dec. 6.....	8	G. O.....	8.37	G. M.....	7.55	.82	3.44	2.26	21.30
Shawnee.	Sept. 13.....	20	S. M.....	14.18	S. G. M.....	9.66	4.52	.....	3.94	24.15
Do.	Sept. 16, 18 ²	19	G. M.....	12.72	G. M.....	8.65	4.07	.....	4.83	19.70
Do.	Oct. 3.....	18	G. O.....	13.50	S. M.....	10.69	2.81	1.13	3.94	19.70
Do.	Oct. 11.....	11	S. G. O.....	11.17	S. L. M.....	8.18	2.99	.....	3.55	17.75
Do.	Oct. 30, 31 ²	20	O.....	11.09	G. O.....	8.71	2.38	1.63	4.01	20.05
Do.	Nov. 14, 15 ²	9	L. M.....	9.27	L. M.....	8.07	1.20	2.31	3.51	17.55
Do.	Nov. 20 ² , 22.....	10	S. G. O.....	9.50	L. M. off colored	6.11	3.39	.....	3.58	17.90
Do.	Dec. 1 ² , 5.....	11	S. L. M. spotted	9.36	L. M.....	4.44	4.92	.....	4.79	23.95
Tahlequah.	Oct. 23.....	19	S. G. O.....	13.96	L. M.....	10.69	3.27	.....	4.08	20.40
Do.	Dec. 13.....	11	O.....	7.10	L. M. spotted	6.55	2.55	.....	4.49	22.45
Do.	Dec. 20.....	9	O.....	7.03	L. M. stained	4.78	2.25	1.81	4.06	20.30
Do.	Dec. 27.....	6	G. O.....	9.32	L. M.....	4.98	4.34	.....	4.34	21.70
Do.	Jan. 3.....	6	O.....	7.20	G. O.....	5.81	1.39	2.56	3.95	19.75
Welchka.	Nov. 2 ² , 30.....	19	S. L. M.....	13.44	L. M.....	10.13	3.31	.....	3.94	19.70
Do.	Nov. 19.....	9	S. G. O.....	10.80	S. L. M.....	8.44	2.36	.....	3.17	15.85
Do.	Nov. 26, 27 ²	10	S. L. M. light stained	10.73	S. L. M.....	8.38	2.35	1.25	3.60	18.00
Do.	Dec. 3 ² , 6.....	9	G. O.....	10.05	S. L. M. spotted	7.55	2.50	.....	3.44	17.20
Do.	Dec. 22 ² , 27.....	6	O.....	5.68	S. G. O.....	3.42	2.26	1.94	2.00	21.00
Do.	Dec. 29 ² , 30.....	2	L. M. stained	6.51	G. O.....	3.28	3.23	.....	3.92	19.60
Do.	Jan. 14.....	9	G. O.....	7.71	S. L. M. spotted	4.97	2.74	1.13	3.87	19.35

¹ On the basis of spot quotations at New Orleans.

² Cases where higher valued bale brought highest comparative price and net differences are shown; all others lower valued bale brought highest comparative price and total differences are shown.

PRICES RECEIVED FOR LINT COTTON COMPARED WITH EQUIVALENT LINT PRICES OF SEED COTTON.

PRICES IN SAME MARKET DURING SAME WEEK.

During the progress of this investigation, an additional survey was made of conditions attending the sale of lint cotton, which resulted in the accumulation of data on the sale of 4,533 bales, which may be considered fairly representative of the entire season and the entire cotton area of Oklahoma. There were 14 instances in which both lint and seed-cotton samples were collected in the same market during the same week. Table IX is presented to show these 14 collections and to compare the prices obtained in marketing cotton by the two methods.

The differences in average selling price per pound have been reached by subtracting the average equivalent lint prices from the average prices of lint cotton without regard to grade. The differences in value on account of grade have been figured on the basis of New Orleans spot quotations. In 3 comparisons, the average value of the lint sold in the seed was found to exceed the average value of the lint sold in the bale, but in all other cases the average value of that sold in the bale was greater. A weighted average of the differences in average value shows that the cotton represented by the lint collections was worth 15 points more than that represented by the seed-cotton collections. If the small gin had turned out as good a quality as that produced by commercial gins, it is probable that the cotton sold in the seed would have appeared approximately equal in value to that sold in the bale, and this difference of 15 points would not have appeared.

TABLE IX.—Comparison between prices received for ginned and unginned cotton in the same market during the same week.

Week ending—	Number of bales sampled.	Average lint price per pound.	Number of loads sampled.	Average equivalent lint price per pound.	Difference in average selling price per pound.	Difference in average value per pound.	Estimated loss—	
							Per pound.	Per bale.
		<i>Cents.</i>		<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	
Sept. 13.....	50	12.79	20	11.67	1.12	0.03	1.09	\$5.45
Sept. 20.....	50	12.95	19	10.75	2.20	1.06	2.26	11.30
Sept. 27.....	49	13.22	11	12.22	1.00	.02	.98	4.90
Oct. 4.....	49	13.41	18	12.34	1.07	.18	.89	4.45
Oct. 11.....	50	12.66	18	10.12	2.54	.32	2.22	11.10
Oct. 18.....	60	12.04	18	10.67	1.37	.06	1.31	6.55
Oct. 25.....	44	12.05	20	10.80	1.25	.11	1.14	5.70
Nov. 1.....	62	12.24	20	10.54	1.70	.48	1.22	6.10
Nov. 8.....	37	11.71	10	10.22	1.49	1.11	1.60	8.00
Nov. 15.....	48	11.21	10	8.67	2.54	.31	2.23	11.15
Nov. 15.....	47	11.35	10	11.44	1.09	.62	1.71	¹ 3.55
Nov. 22.....	32	11.86	11	9.47	2.39	.46	1.93	9.65
Nov. 22.....	83	10.67	10	8.50	2.17	.08	2.09	10.45
Nov. 29.....	22	10.76	10	7.61	3.15	1.39	3.54	17.70
Summary.....	683	12.07	205	10.56	² 1.67	.15	1.52	7.59

¹ Indicates particular figures in favor of seed cotton; all others in favor of lint cotton.

² Indicates a gain; all other extensions represent losses.

³ The summarized difference in average selling price has been reached by weighting by the number of loads.

It will be noticed that, of the 14 comparisons, 1 shows a gain of \$3.55 per bale by selling the cotton unginned and 13 show a loss ranging from \$4.45 to \$17.70. The 205 samples of seed cotton show an average loss of 1.52 cents per pound of lint or \$7.59 per bale.

A comparison between primary prices of individual bales and equivalent lint prices of individual loads in the same market during the same week showed that wide price variations occurred. One bale of Middling sold for 13.25 cents against one load yielding the same grade at an equivalent lint price of 9.98 cents. One bale of Low Middling sold for 12 cents, while one load of the same grade brought an equivalent of 7.56 cents. A Low Middling bale sold for 12.30 cents in contrast with a Strict Low Middling load at 8.18 cents. Three bales of Strict Low Middling sold at an average of 12.25 cents, while three loads of the same grade brought an average equivalent of 9.93 cents.

PRICES FOR EACH GRADE DURING SEASON THROUGHOUT STATE.

Table X is presented in order to compare for the entire season the average prices received for the several grades of cotton when sold in the bale with the average prices received when sold in the seed. Only the white grades have been included in this comparison. The custom in the Oklahoma primary markets of classing no cotton above Good Middling has been followed and all Good Middling and better samples have been grouped together as Good Middling.

TABLE X.—Comparison by grades, between prices secured for cotton when sold unginned and when sold in the bale, during the entire season in the markets represented.

Grade.	Cotton sold in bales.		Cotton sold in seed.			Estimated loss by selling unginned.	
	Number of bales sampled.	Price per pound.	Number of loads sampled.	Price of seed cotton.	Equivalent lint price.	Per pound.	Per bale.
		<i>Cents.</i>				<i>Cents.</i>	
G. O.....	152	9.47	46	\$3.04	\$8.56	0.91	\$4.55
S. G. O.....	364	10.39	72	3.48	9.74	.65	3.25
L. M.....	504	11.25	108	3.84	10.90	.35	1.75
S. L. M.....	665	11.99	141	3.96	11.27	.72	3.60
M.....	661	12.63	111	4.01	11.25	1.38	6.90
S. M.....	314	13.01	57	4.04	11.53	1.48	7.40
G. M.....	342	13.04	51	4.03	11.52	1.52	7.60

It will be observed that the prices of cotton sold both before and after ginning increased in a general way as the grade improved. This was due in a large measure to the fact that most of the high grade bales were sold while the prices were relatively high and most of the low grade bales were sold while the prices were relatively low. However, as the proportion of the different grades of cotton sold in the seed should vary throughout the season, as they do in cotton sold in the bale, the figures are comparable for the entire season.

The losses by selling in the seed range from 35 points, or \$1.75 per bale for Low Middling, to 152 points, or \$7.60 per bale for Good Middling. Selling the cotton unginned caused an aggregate loss of \$2,715.20 on the 586 loads here represented, or an average loss of \$4.63 for each bale. Thus it is shown that the producer who sells his cotton unginned lost on each grade, and that the losses on the higher grades exceeded those on the lower grades.

PRICES FOR EACH MONTH DURING SEASON THROUGHOUT STATE.

Table XI has been prepared in order to compare the prices obtained for cotton by the two systems of marketing, during each month and throughout the season. Twenty-nine lint samples of extra staple have been omitted from this table, but the remaining 4,504 bales and the 881 loads sampled have been considered. The number of samples of both lint and seed cotton for each month, the average prices secured for lint and seed cotton, the average equivalent lint prices and the estimated losses per pound and per bale are shown.

TABLE XI.—*Comparison, by months, between prices secured for cotton when sold unginned and when sold in the bale during the entire season in the markets represented.*

Month.	Cotton sold in bales.		Cotton sold in seed.			Estimated loss by selling unginned.	
	Number of bales sampled.	Average price per pound.	Number of loads sampled.	Average price per 100 pounds.	Average equivalent lint price per pound.	Per pound.	Per bale.
		<i>Cents.</i>			<i>Cents.</i>	<i>Cents.</i>	
September.....	585	13.12	104	\$4.03	11.62	1.50	\$7.50
October.....	1,873	12.46	315	4.09	11.69	.77	3.85
November.....	1,607	10.95	253	3.55	9.94	1.01	5.05
December.....	333	9.74	182	2.84	7.69	2.05	10.25
January.....	106	8.16	27	2.62	6.68	1.48	7.40
Summary.....	4,504	11.70	881	3.62	10.20	1.21	6.06

¹ These figures have been reached by weighting the losses by the number of loads sampled in each month.

A loss is shown for each month ranging from an average of \$3.85 per bale in October to \$10.25 per bale in December. The average baled lint price for the entire season is shown as 11.70 cents and the average equivalent lint price for the entire season as 10.20 cents. There occurred an average loss of 1.21 cents per pound or \$6.06 per bale.

A STUDY OF CONDITIONS IN A SPECIFIC LOCALITY.

In order to determine the prices paid for seed cotton and to compare the prices paid for Triumph cotton with the prices paid for other varieties, the town of Crowder was chosen, as activities in that locality had resulted in a large percentage of production of Mebane's Triumph cotton. Each week an equal number of samples of Triumph and other varieties of seed cotton were collected simultaneously. The Triumph samples were taken from loads belonging to farmers who were well known as producers of this variety, while the other

samples were taken indiscriminately and may include some Triumph cotton.

These collections were made between November 22 and January 19 and resulted in the accumulation of 27 Triumph and 28 other samples, a comparison of which is shown in Table XII. As the first part of the season was not covered, the average grade of both lots was below that of the season, but this fact does not affect the comparison during the period under consideration.

TABLE XII.—*Comparison between Triumph and other seed-cotton sales in Crowder, Okla.*

Varieties.	Number of loads sampled.	Approximate grade average.	Lint outturn.	Seed outturn.	Trash outturn.	Seed cotton price per 100 pounds.	Equivalent lint price per pound.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Cents.</i>
Triumph.....	27	L. M....	34.4	63.5	3.6	\$3.67	9.52
Other.....	28	S. G. O..	33.1	64.2	4.2	3.13	8.23
Summary.....	55	.....	33.7	63.9	3.9	3.39	8.86

Table XII shows that Triumph had a distinct advantage over the miscellaneous varieties commonly grown in this neighborhood. The quality is shown to be a full grade higher, which is probably explained by the fact that it was produced by more careful growers. The lint outturn was 1.3 per cent greater and the price paid for the unginned cotton 54 cents per hundred pounds more. The average prices paid for the unginned cotton were: For Triumph \$3.67, and for other varieties \$3.13 per hundred pounds, which, when converted to the equivalent baled lint prices, are 9.52 cents and 8.23 cents per pound, respectively, a difference in favor of Triumph of 1.29 cents per pound. After allowing 50 points for difference in grade, 0.79 cent per pound, or \$3.95 per bale more was paid by the ginner for Triumph than for other cotton.

No statistics were obtained on prices paid for lint cotton in this immediate vicinity, but the prices paid for these 55 loads when expressed in equivalent baled-cotton prices show an average of 8.86 cents per pound for this cotton, about half of which was Triumph, carefully picked and handled. Comparing this average with the average lint price of 9.87 cents throughout the State during this period as determined by the survey of lint cotton sales, it is found that on each pound of cotton sold unginned in this market the growers sustained an average loss of 1.01 cents, and on each bale an average loss of \$5.05. It is evident that the producers of this section, both as individuals and as a community, would profit by having their cotton custom ginned, thereby eliminating the various uncertain factors that exist when cotton is sold in the seed and reaping the benefit of the high percentage of outturn of lint and low percentage of trash, and the good character of their cotton. The activities in

the interest of pure seed, improved culture, and careful picking should be extended to include the encouragement of custom ginning and a knowledge of the quality and value of cotton before marketing.

The facts brought out by the study of the situation at Crowder are published because it is believed that they are typical of conditions in many other localities where cotton is sold in the seed and where efforts to improve the product of the community are being made.

CONCLUSIONS.

The wide variations in the lint, seed, and trash proportions of seed cotton, together with the impracticability of determining accurately these percentages and the quality of the cotton before it is ginned, make it impossible for the ginner justly to discriminate between the value of individual loads. The uncertainties thus involved cause buyers to base their prices on the average outturns and average grades of the particular community and the current lint and seed prices.

This practice results in variations between the prices paid for the lint content of different loads of seed cotton. Wide differences in prices have been shown to exist between the lint content of loads in each market and between loads in the different markets investigated. Where lint and seed cotton are sold in the same market there is also an inequality between prices paid for lint cotton and for the lint content of seed cotton. In some instances, individual farmers have received more for their product in the seed than they would have received by selling in the bale; however, in most cases, and in the aggregate, a loss has been shown on each grade during each month and throughout the entire season by selling cotton in the seed.

Therefore this method of marketing cotton as a general practice, can not be condemned too strongly, and both the farmer and ginner are advised for the common good of all to encourage custom ginning, so that it may be possible to sell each bale on its merits.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 351

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 22, 1916

THE TERRAPIN SCALE:
AN IMPORTANT INSECT ENEMY OF
PEACH ORCHARDS

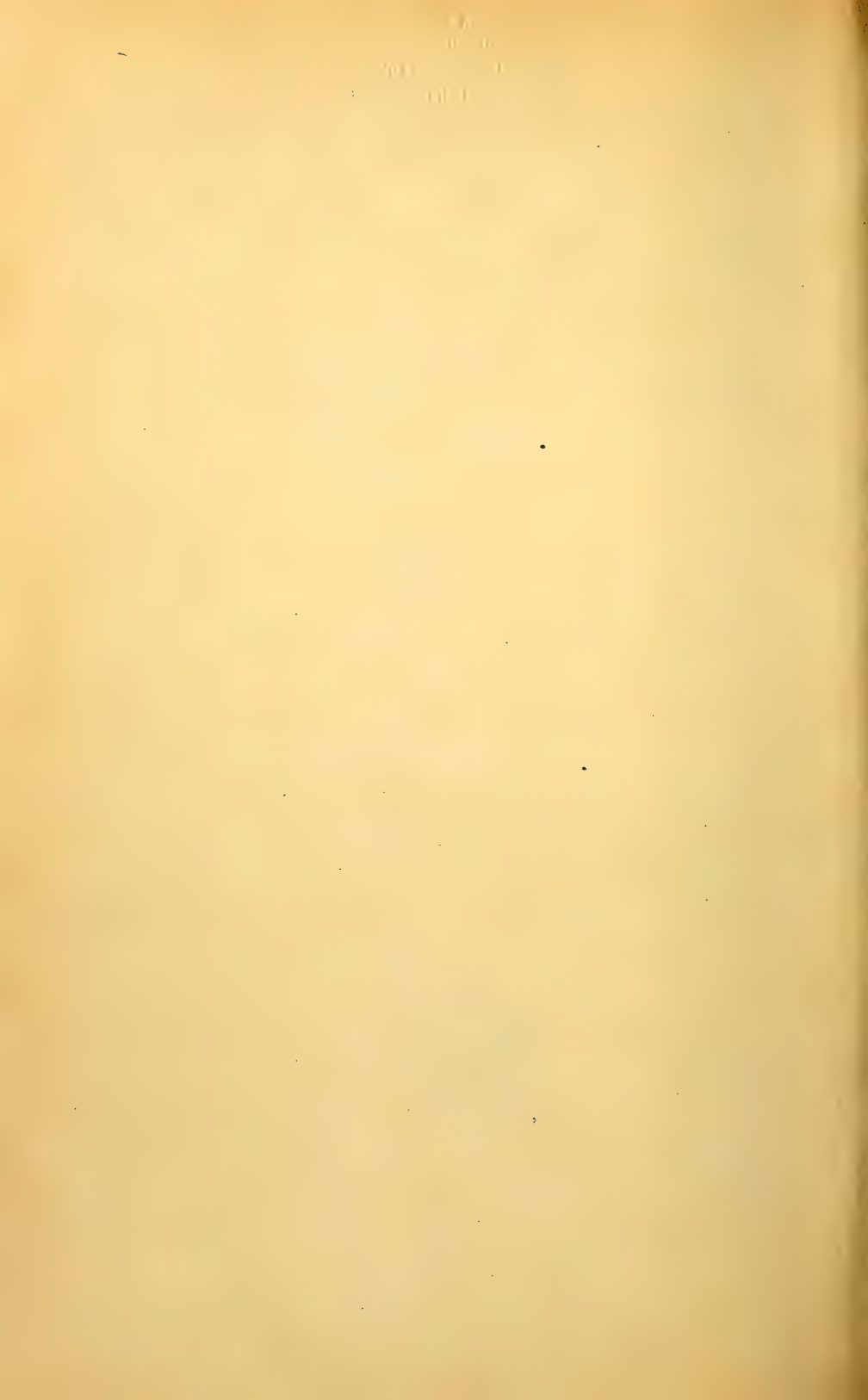
By

F. L. SIMANTON, Entomological Assistant, Deciduous Fruit
Insect Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 353

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 16, 1916

MOISTURE CONTENT AND SHRINKAGE
OF FORAGE

AND THE RELATION OF THESE FACTORS TO
THE ACCURACY OF EXPERIMENTAL DATA

By

H. N. VINALL, Agronomist, and ROLAND McKEE,
Assistant Agrostologist, Office of Forage-Crop
Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 354

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.



October 20, 1916

FORESTS OF PORTO RICO
PAST, PRESENT, AND FUTURE
AND THEIR PHYSICAL AND ECONOMIC ENVIRONMENT

By

LOUIS S. MURPHY, Forest Examiner

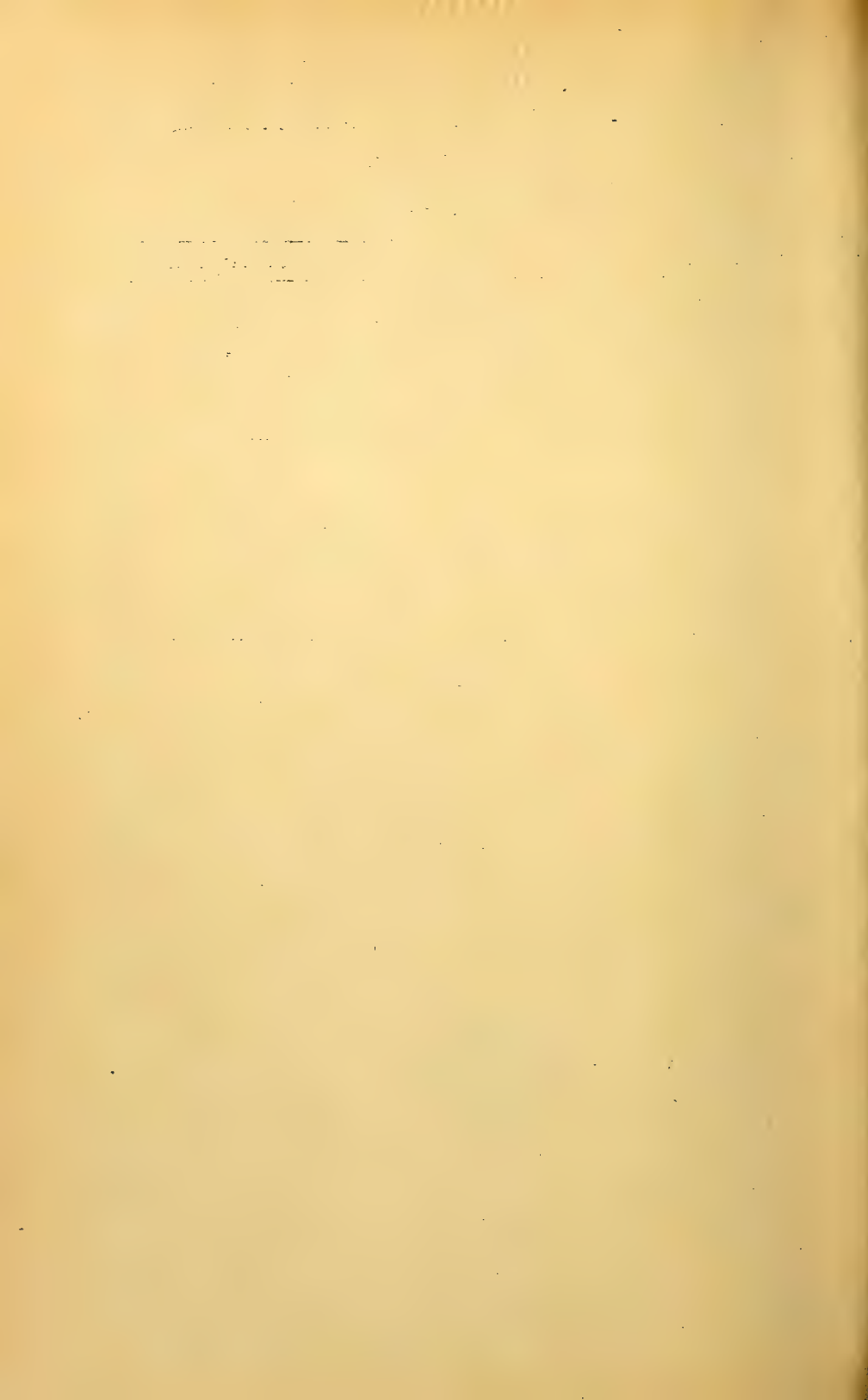
In Cooperation with the Government of Porto Rico Board of Commissioners
of Agriculture. John A. Wilson, Temporary President,
Succeeded by Tulio Larrinaga, President

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 355

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

April 13, 1916

EXTENSION COURSE IN SOILS

FOR SELF-INSTRUCTED CLASSES IN MOVABLE
SCHOOLS OF AGRICULTURE

By

A. R. WHITSON, Professor of Soils, University of Wisconsin,
and H. B. HENDRICK, Assistant in Agricultural
Education, States Relations Service

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 358

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

April 12, 1916

STUDIES OF THE
MEXICAN COTTON BOLL WEEVIL IN
THE MISSISSIPPI VALLEY

By

R. W. HOWE, Entomological Assistant, Southern Field Crop
Insect Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 360

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

June 17, 1916

MISTLETOE INJURY TO CONIFERS
IN THE NORTHWEST

By

JAMES R. WEIR, Forest Pathologist, Office of
Investigations in Forest Pathology

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 362

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.

May 6, 1916

A SYSTEM OF ACCOUNTS FOR
PRIMARY GRAIN ELEVATORS

By

JOHN R. HUMPHREY, Assistant in Market Business Practice
and W. H. KERR, Investigator in Market Business Practice

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 365

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief,
and the Bureau of Animal Industry, A. D. MELVIN, Chief

Washington, D. C.

PROFESSIONAL PAPER

September 8, 1916

LARKSPUR POISONING OF LIVE STOCK

By

C. DWIGHT MARSH and A. B. CLAWSON, Physiologists, Poisonous Plant
Investigations, Bureau of Plant Industry, and HADLEIGH MARSH,
Veterinary Inspector, Bureau of Animal Industry

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 367

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

June 23, 1916

CARRYING CAPACITY OF
GRAZING RANGES IN SOUTHERN
ARIZONA

By

E. O. WOOTON, Agriculturist, Office of Farm Management

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 370

Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER July 20, 1916

THE RESULTS OF PHYSICAL TESTS
OF ROAD-BUILDING ROCK

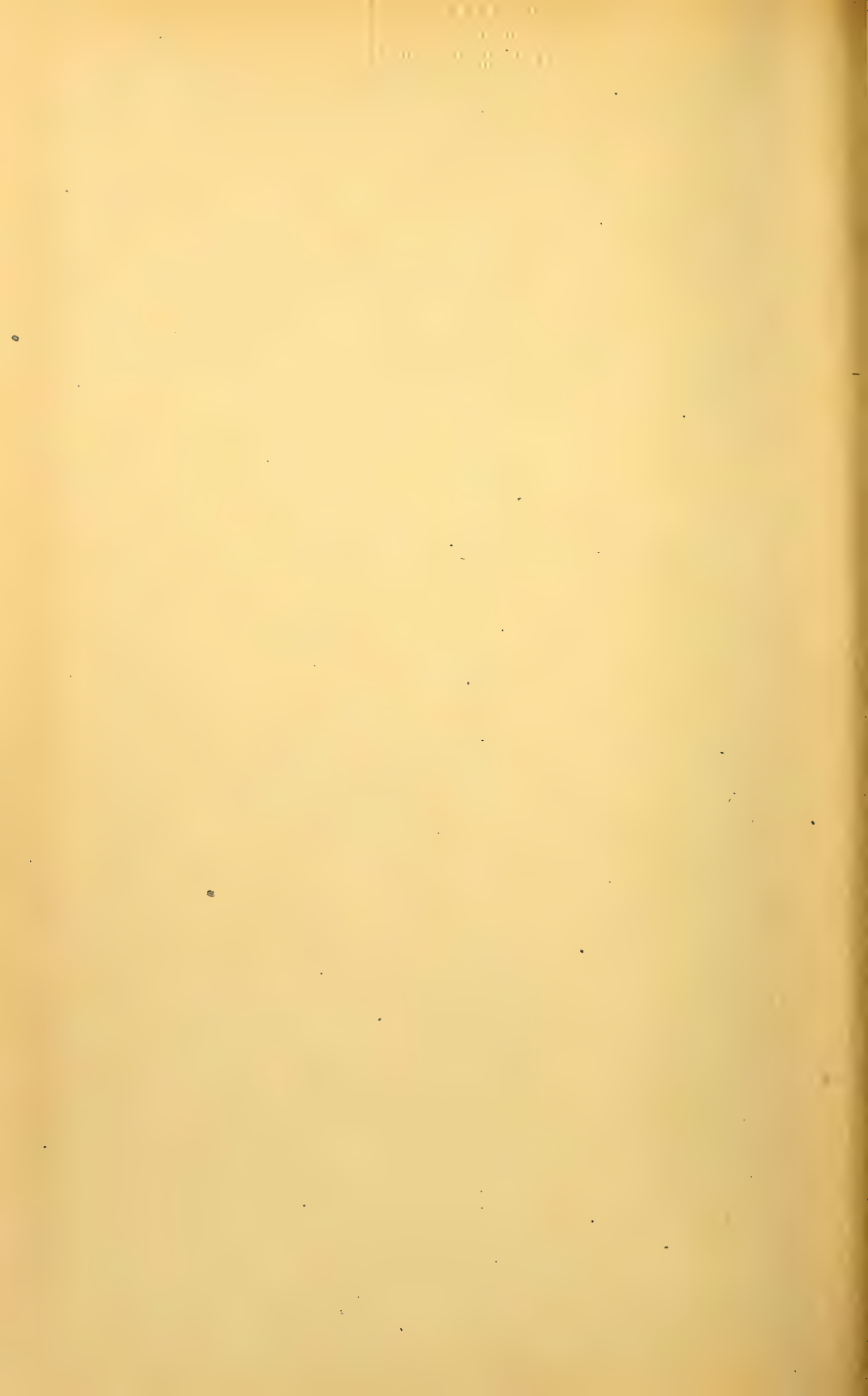
By

PREVOST HUBBARD, Chemical Engineer, and FRANK H.
JACKSON, Jr., Assistant Testing Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 373

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

August 25, 1916

BRICK ROADS

By

VERNON M. PEIRCE, Chief of Construction, and
CHARLES H. MOOREFIELD, Senior Highway Engineer

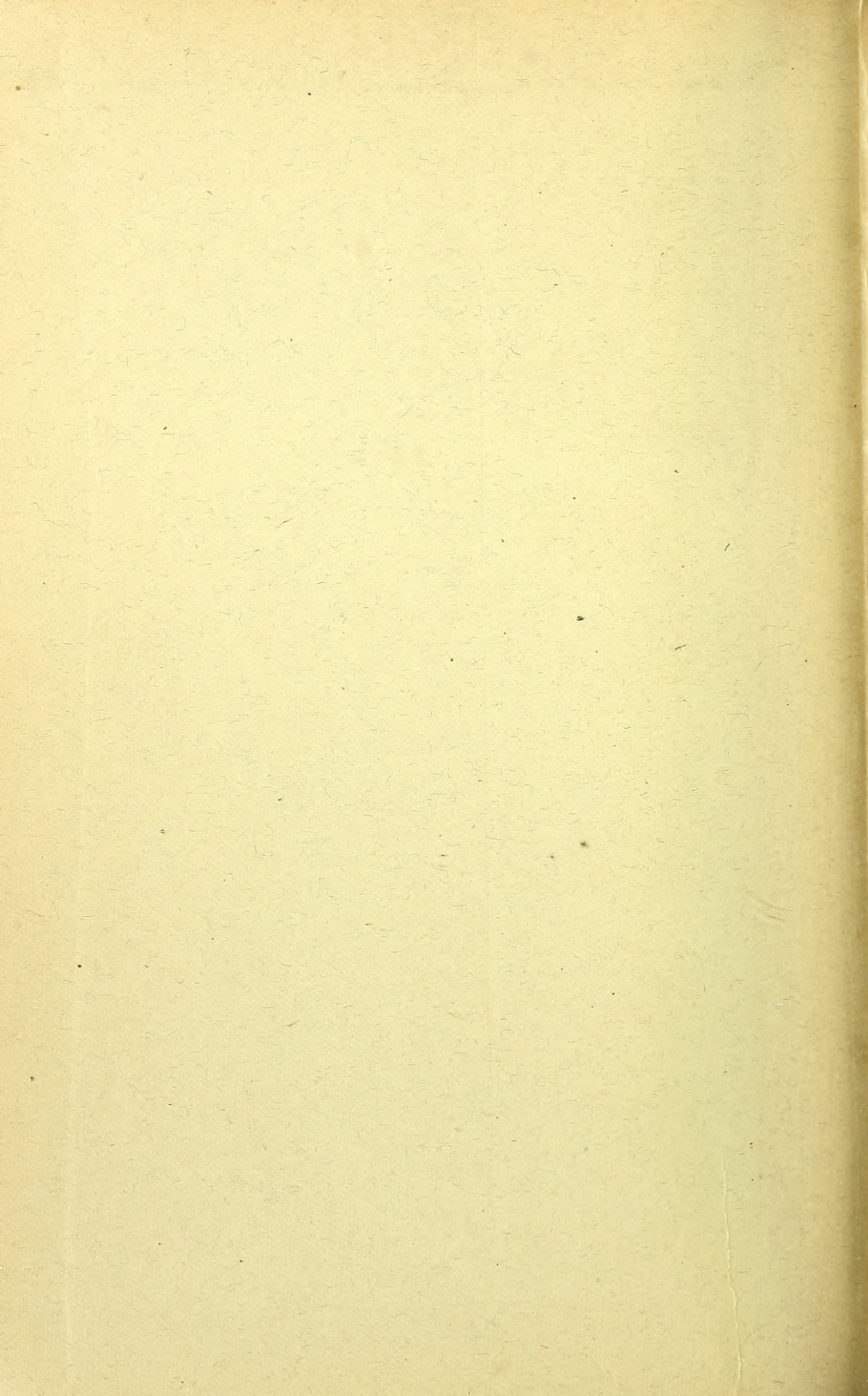
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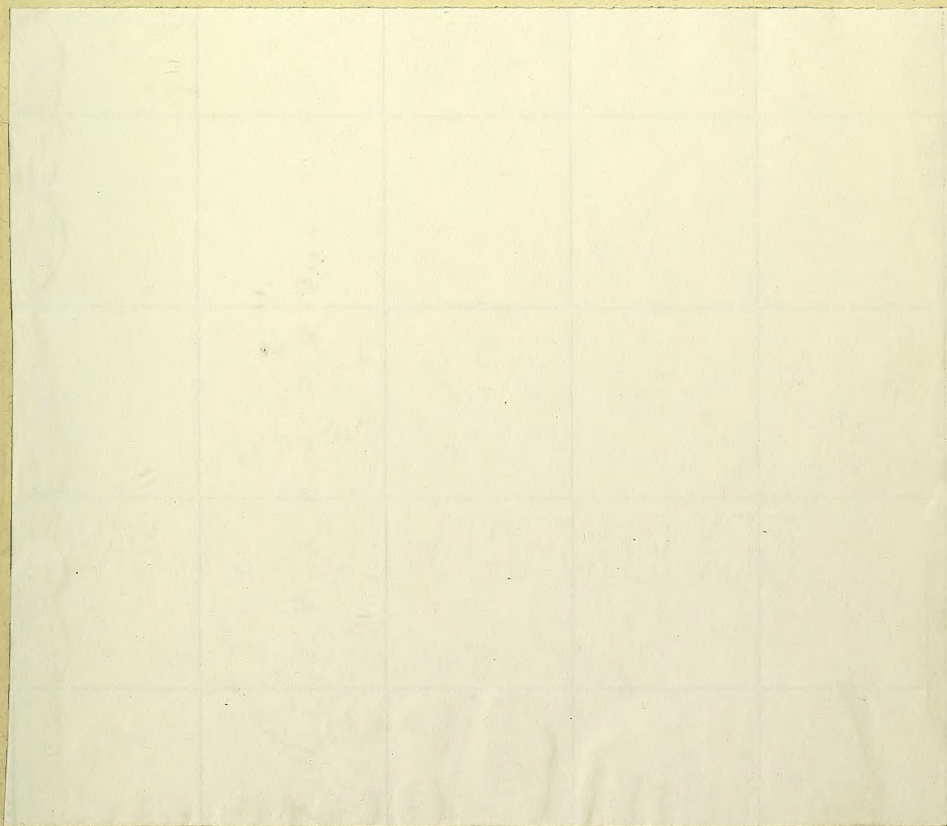
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